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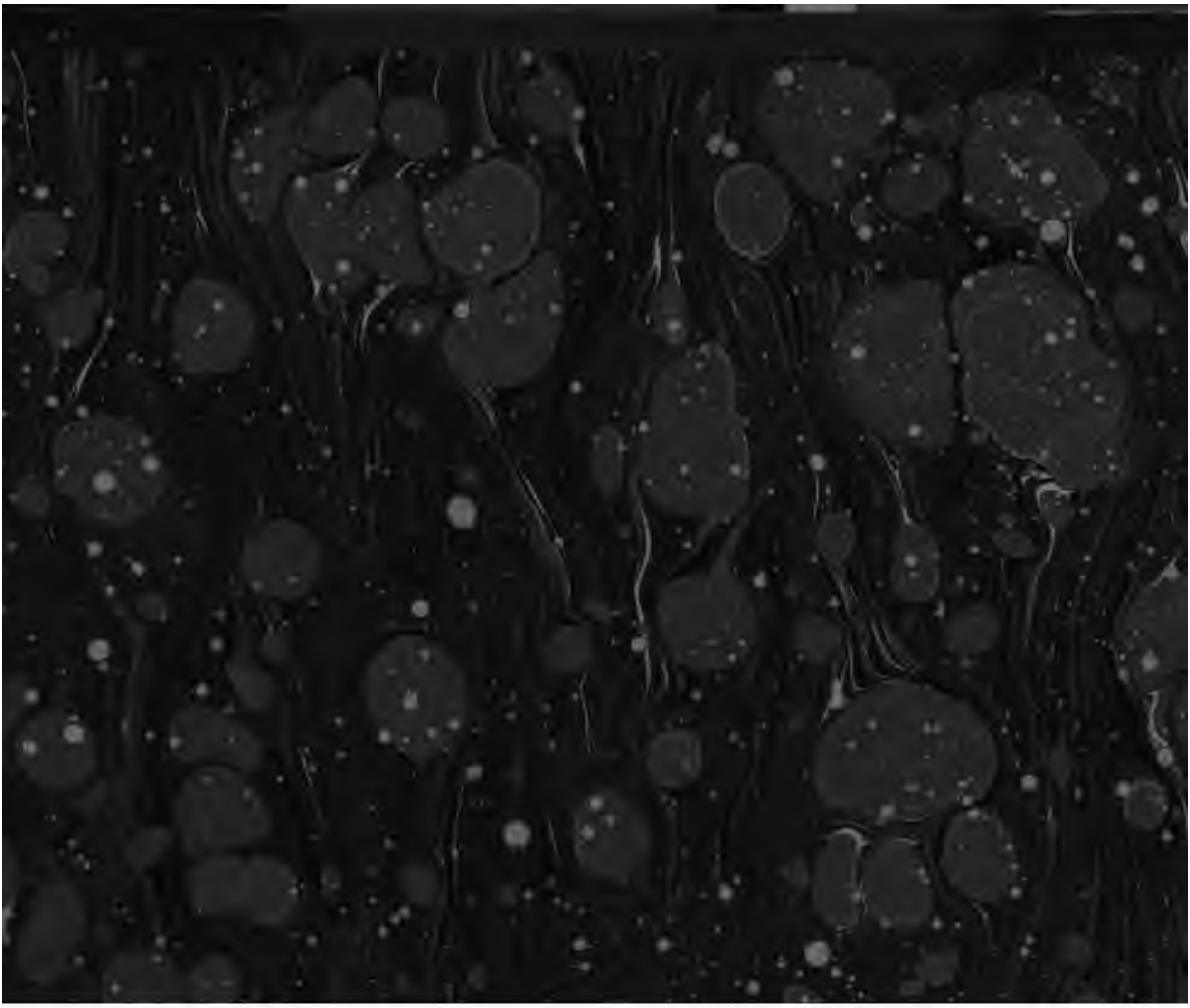

LINK-MOTION

AND

EXPANSION-GEAR,

PRACTICALLY CONSIDERED.

ILLUSTRATED WITH
NINETY PLATES, AND TWO HUNDRED AND TWENTY-NINE WOODCUTS.

BY

N. P. BURGH, ENGINEER.

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PREFACE.

Of course, as with nearly all my books, when I commenced this one, it was to be two-thirds of its present size at the most, but as I progressed it grew beyond my anticipations, with a corresponding amount of labour; as for example, I found the inventions of valve-gears were so numerous that it involved the process of "winnowing" pretty hard, to blow off the "chaff," which, I need scarcely say, exceeded the "grain" by far: but this was not all, for in many instances the particularities of an invention were so seductively extolled by the inventor, that it was only after close and patient investigation they were discovered to be worthless, and thus kept back from appearing here. In other cases I have been amused at the presumption an inventor fell into with his idea, showing thereby a total blindness of the real requirements. Perhaps the most amusing lesson I learnt was, that the less an inventor knew of what he patented, the more he claimed; while in many cases the same arrangement was patented over and over again with all different claims, or it was one claim embraced all that had been done and more to follow: indeed our Patent Record Library is as amusing a lounge-room as need be for those who will take the trouble to read some of its contents.

From about five hundred examples of valve-gears, patented and not, I selected about one hundred and thirty as being worthy of notice, to appear in the "History of the Practical Application;" added to which I have illustrated over fifty examples of valves; many examples of cam, lever, and crank, motions; starting gears, and other matter; making together more than two hundred and twenty examples, as used from the year 1775 to 1870, or extending over a period of one hundred and five years, arranged in the following order. Adjustable eccentrics and gears, twenty-seven examples. Cams and gears, ten. Cranks, levers, and gears, fourteen. "Corliss" valve-gears, thirteen. Dash-pot and gears, eight. Diagrams, thirty-five. Single eccentrics and gears, eighteen. Expansion gears, twelve. Link motions, fifty-three. Rotary valve-gears, fifteen. Starting and reversing gears, six; and valves, fifty-four examples—being a total of two hundred and sixty-five illustrations.

My letter-press matter has been prepared with care as to the veracity of all the statements relating to the "History." I have the honour also of having brought to light the "History of the Invention of the Link Motion," which appears as the introduction.

Chapter I. explains the Principles of the action of Steam Working Valves.

Chapter II. is the History of the Practical Application of Valve-gearing, commencing at the year 1710, which is the earliest record of the steam engine we have. This is the main portion of the work, for it extends through one hundred and eighty-five pages, and contains one hundred and eighty-six illustrations.

The plates that are in this work contain more genuine information on this subject than has ever yet appeared; their value also is unequalled as a reference, because each firm who supplied the original drawings sent in their best examples carefully dimensioned and drawn to scale with all the little practical errors which occur during construction faithfully corrected.

Having the confidence of the leading Marine Engineers, I of course have general latitude in my selection of examples of work carried out for illustration in my books; and I trust my readers will be satisfied with my judgment for their benefit in the present case.

On former occasions I have had to confine my thanks to my friends, Messrs. Penn, Langdon, Barclay, Rennie, Field, Humphrys, Dudgeon, Spencer, Ravenhill, and Napier, which are of course repeated now, but extended to the gentlemen whose additional names appear in this work as contributors.

The subjects forming the plates are thus arranged: Beam Engine Valve-Gear, 7 examples; "Corliss" Valve-Gear, 14; Governor Gears and Valves, 3; Marine Expansion Gears, 17; Marine Reversing Gears, 27; Marine Link-Motion, 36; Locomotive Link-Motion, 12; and Geometrical Plates, 10; making 126 examples of Valve-Gearing, &c., practically accomplished, and proved to be worthy of record.

Of my performance in this work, I say nothing, and I leave the result of my labours to the judgment of those who can best appreciate labour honestly discharged.

N. P. Burgh.

78, Waterloo Bridge, London.
July, 1870.

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THE

HISTORY OF THE INVENTION OF THE LINK-MOTION.

BY N. P. BURGH.

INTRODUCTION.

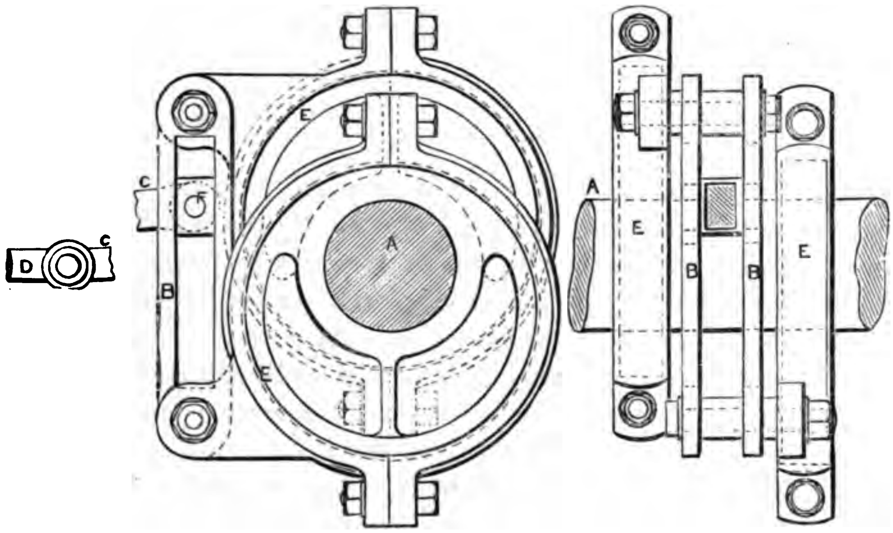
No part of the steam engine demands as much attention as the valve gear, inasmuch that the valve may be all right, but if the gear is imperfect then the proper working of the valve is impossible; and of all the valve gears yet known the original common link motion is not only the most simple but the best also. As a consequence, therefore, the invention of it must have conferred a great benefit on the engineering world, because the locomotive engine, the marine engine, and the reversing, stationary, and portable land engines would in great measure be incomplete and imperfect without it. This is more obvious when it is remembered that the link motion is not only available as a reversing gear, but also as an expansion gear of the most simple and effective order, with the advantage too of regulating the points and limit of cut-off by the valve without any additional detail.

The inventor of the link motion in its simplest, original, and best form is Mr. W. Howe, who introduced it in the month of August, in the year 1842. He was then a working mechanic in the employment of Messrs. Robert Stephenson and Co., engineers, Newcastle-on-Tyne.

The history of the invention may now be given in Mr. Howe's own language, as expressed to the writer:—A species of link motion (shown by Fig. 1 on the next page) was, just before this date, suggested by

Mr. Williams, who was a young gentleman apprentice in the works at the time. This is shown by side and end elevations. A indicates the crank shaft, B the proposed link, C is the connecting rod, connecting the link to the valve rod D; E, E, are the eccentrics, and F the block for reversing the motion of the valve and engine. It will be easily seen that this suggestion could never have been of the least practical use, because one eccentric band would displace the other when in motion.

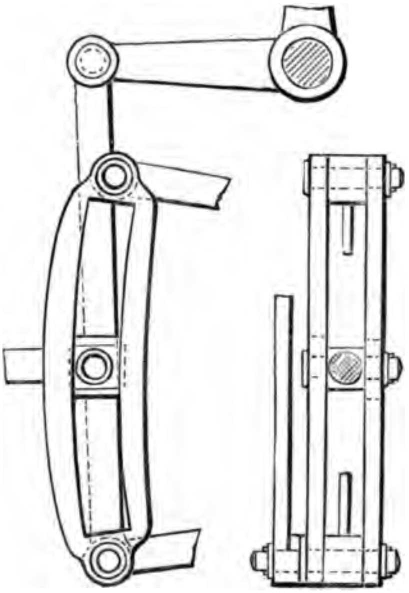
Fig. 1.



Williams's Link-Motion, as suggested by him in the year 1842.

once saw the worth of its application practically, not only as a reversing, but also as an expansion gear for working the slide valve, and he (Mr. Hutchinson) sent the model at once to Mr. Robert Stephenson, then in London, who also approved of it immediately he saw it.

FIG. 2.



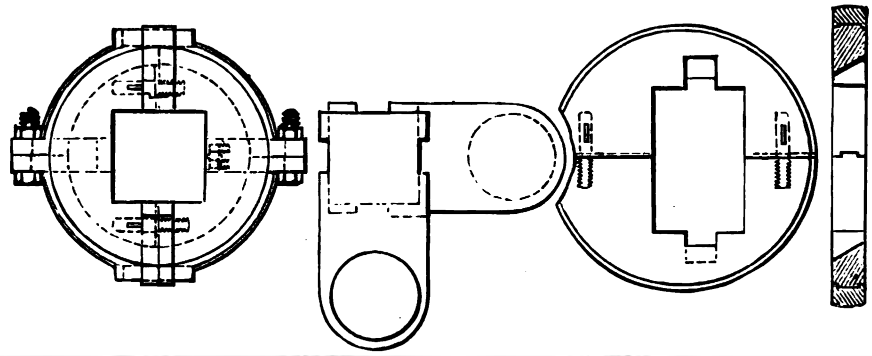
Elevations of the Original Link-Motion invented by W. Howe, in the beginning of the year 1842, while in the employment of Messrs. Robert Stephenson and Co., Newcastle-on-Tyne.

At that time (1842) two locomotives were being made at the works for the North-Midland Railway Company—now a portion of the Midland branches. These engines were to have been fitted with Dodd's wedge motion. Their numbers were 358 and 359 in Messrs. Stephenson's books, but 70 and 71 on the North Midland Railway. One of the locomotives (No. 70) had the wedge motion fitted to it, as shown by Fig. 3 on the next page; but as soon as Mr. Howe brought out the link motion it was put on No. 71 instead of the wedge kind. He was at that time engaged in making a working model of the wedge motion as applied to No. 70, but as soon as he invented his link motion he was instructed to throw the other aside, and make a full-size model of his kind, which he did, and thus fully proved the adaptation of the link motion for any grade of cut-off by the slide valve; and as the model included the sections of the cylinder, piston, and slide valve, the points of cut-off for each stroke of the piston were readily seen. The valve had only $\frac{1}{2}$ inch outside lap, and $\frac{1}{16}$ inch inside lap; the opening caused by the valve for the admission of the steam was 1 inch, making the throw of the eccentric $1\frac{1}{2}$ inch, and the travel of the valve 3 inches; the length of the eccentric rods was 5 feet, and thus the lead was practically constant, as shown by the following table:—

Tabular Statement of the Working of Howe's Link-Motion fitted to No. 71 Locomotive Engine on the North-Midland Railway, constructed in 1842.

Notch.	Valve travel.	Steam port open.	Supply lead.	Cut-off at stroke of piston.	Exhaust port open.	Ratio of expansion.	Ratio of exhaustion.	Exhaustion lead.
	Inches.	Inches.	Inches.	Inches.	Inches.			
1	$2\frac{3}{16}$	$\frac{7}{8}$	$\frac{1}{8}$	$17\frac{1}{8}$	$19\frac{1}{8}$	2	$\frac{7}{8}$	$\frac{9}{16}$
2	$2\frac{1}{2}$	$\frac{3}{4}$	$\frac{1}{8}$	$16\frac{1}{4}$	$18\frac{3}{4}$	$2\frac{1}{2}$	$1\frac{1}{4}$	$\frac{9}{16}$
3	$2\frac{1}{4}$	$\frac{5}{8}$	$\frac{1}{8}$	$14\frac{7}{8}$	$18\frac{1}{8}$	$3\frac{1}{4}$	$1\frac{7}{8}$	$\frac{9}{16}$
4	2	$\frac{1}{2}$	$\frac{1}{8}$	13	$17\frac{1}{8}$	$4\frac{1}{8}$	$2\frac{7}{8}$	$\frac{9}{16}$
5	$1\frac{3}{4}$	$\frac{3}{8}$	$\frac{1}{8}$	$10\frac{3}{8}$	$15\frac{3}{4}$	$5\frac{3}{8}$	$4\frac{1}{4}$	$\frac{9}{16}$
6	$1\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{8}$	$7\frac{3}{4}$	14	$6\frac{5}{8}$	6	$\frac{9}{16}$
7	$1\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{8}$	$4\frac{1}{4}$	$11\frac{1}{2}$	$7\frac{1}{4}$	$8\frac{1}{2}$	$\frac{9}{16}$

FIG. 3.



Tabular Statement of the Working of Dodd's Wedge-Motion fitted on No. 70 Locomotive, on the North Midland Railway, in 1842.

Notch.	Valve travel.	Steam port open.	Supply lead.	Cut-off at stroke of piston.	Exhaust port open.	Ratio of expansion.	Ratio of exhaustion.	Exhaustion lead.
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
1	$3\frac{3}{4}$	$\frac{7}{8}$	$\frac{1}{8}$	$14\frac{1}{2}$	$18\frac{1}{8}$	$3\frac{5}{8}$	$1\frac{7}{8}$	1
2	$3\frac{11}{16}$	$\frac{13}{16}$	$\frac{1}{8}$	$14\frac{1}{8}$	$18\frac{1}{8}$	4	$1\frac{7}{8}$	1
3	$3\frac{1}{2}$	$\frac{3}{4}$	$\frac{1}{8}$	13	$17\frac{7}{8}$	$4\frac{7}{8}$	$2\frac{1}{8}$	1
4	3	$\frac{1}{2}$	$\frac{1}{8}$	11	$16\frac{7}{8}$	$5\frac{7}{8}$	$3\frac{1}{8}$	1
5	$2\frac{9}{16}$	$\frac{1}{4}$	$\frac{1}{8}$	$7\frac{1}{2}$	$15\frac{1}{2}$	8	$4\frac{1}{2}$	1
6	$2\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{8}$	$3\frac{1}{4}$	$12\frac{1}{4}$	9	$7\frac{3}{4}$	1
7	$2\frac{3}{16}$	$\frac{1}{8}$	$\frac{1}{8}$	1	$8\frac{7}{8}$	$7\frac{7}{8}$	$11\frac{1}{8}$	1

Cylinders, 14in. diameter; stroke of piston, 20in.; steam ports, 10in. long and $1\frac{1}{4}$in. wide; outside lap of the slide valve, 1in.; inside lap, $\frac{1}{16}$in., as for No. 71.

The link is represented by Fig 2. in side and end elevations, but its application to the first engine in practice was on September 10th, 1842, as is shown by Fig. 4 in plan and side elevation on the next page.

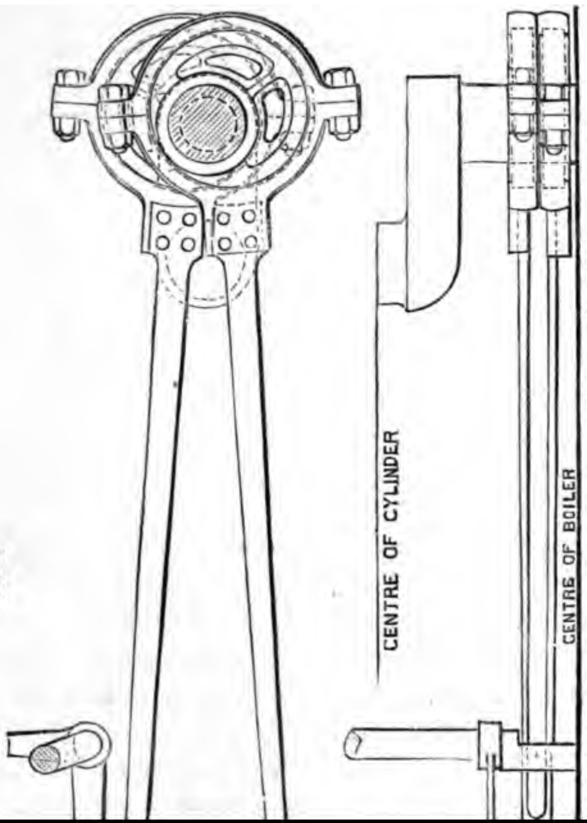
About that time there were divided opinions as to the efficiency of this link motion; but Mr. Robert Stephenson settled the question by adopting it, and acknowledged that Mr. Howe was the inventor also by instructing his cashier to make him a present of twenty guineas for his invention, and afterwards, as a further recognition, appointed him, in 1846, to be engineer of the Stephenson Collieries and Ironworks at Clay Cross, Chesterfield, where he is now.

Being thus placed in a more independent position, Mr. Howe had an opportunity of applying the link motion in many ways to various classes of engines, and in the year 1847 he designed and applied the first link motion to a winding engine with success.

This motion was the twin-solid link-type, as shown by Fig. 5 in plan and side elevation; and Fig. 6 is a side elevation and sectional plan of the same link, as illustrated on page 7.

The illustration, Fig. 7 on page 8, is a plan and side elevation of the

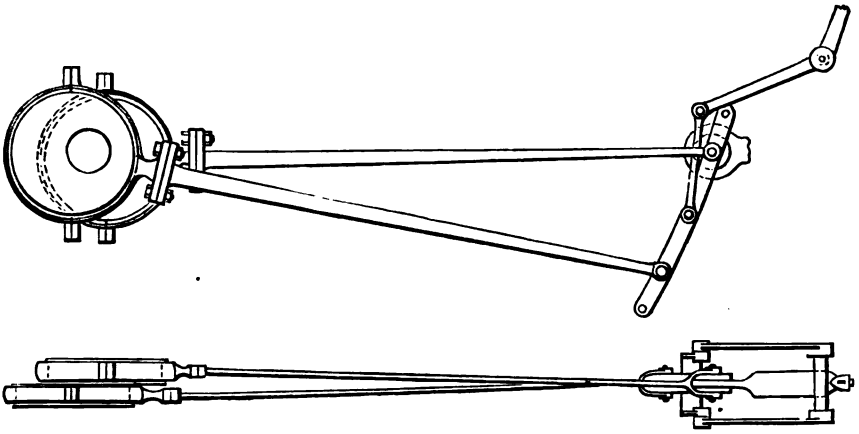
FIG 4.



we's Link-Motion as Applied by Messrs Robert Stephenson and Co. in the year 1842.

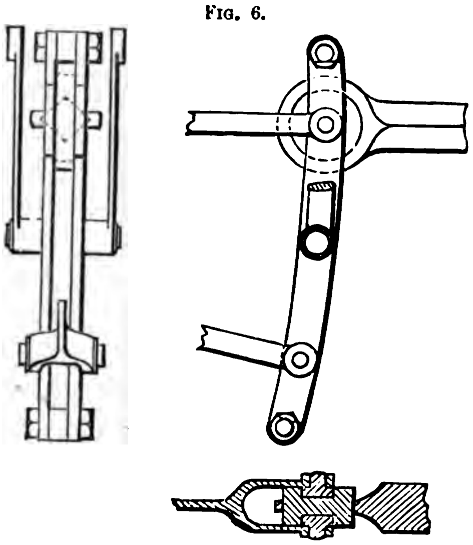
valve gearing and a portion of the winding engine mentioned; and Figs. 8 and 9 illustrate the principal details of the starting gear and link.

FIG. 5.



Arrangement of Howe's Twin Bar-Solid Link-Motion, invented by him, and applied to one of the Winding Engines at Clay Cross Works in the year 1847.

FIG. 6.



Detailed Views of Howe's Twin "Solid" Link-Motion as shown by Fig. 5.

It should be mentioned here that the vibrating block, enclosing the link that worked in the eye of the valve rod, was made of brass; and the eye of wrought iron was not case-hardened, and as the "wear" was considerable in consequence, the adjustable head for the twin-bar link was invented by W. Howe in the year 1848, as illustrated by Fig. 10 in side elevation and sectional plan on page 11.

The means of adjusting the wearing surface consisted of putting the link block in halves in an ordinary connecting rod head, with the usual strap, gibs, and cotter, so that the halves could be keyed up when required.

A full-sized model link, on this principle, was made, and Fig. 11 on page 12 is a perspective view of it from a photograph since taken, as the

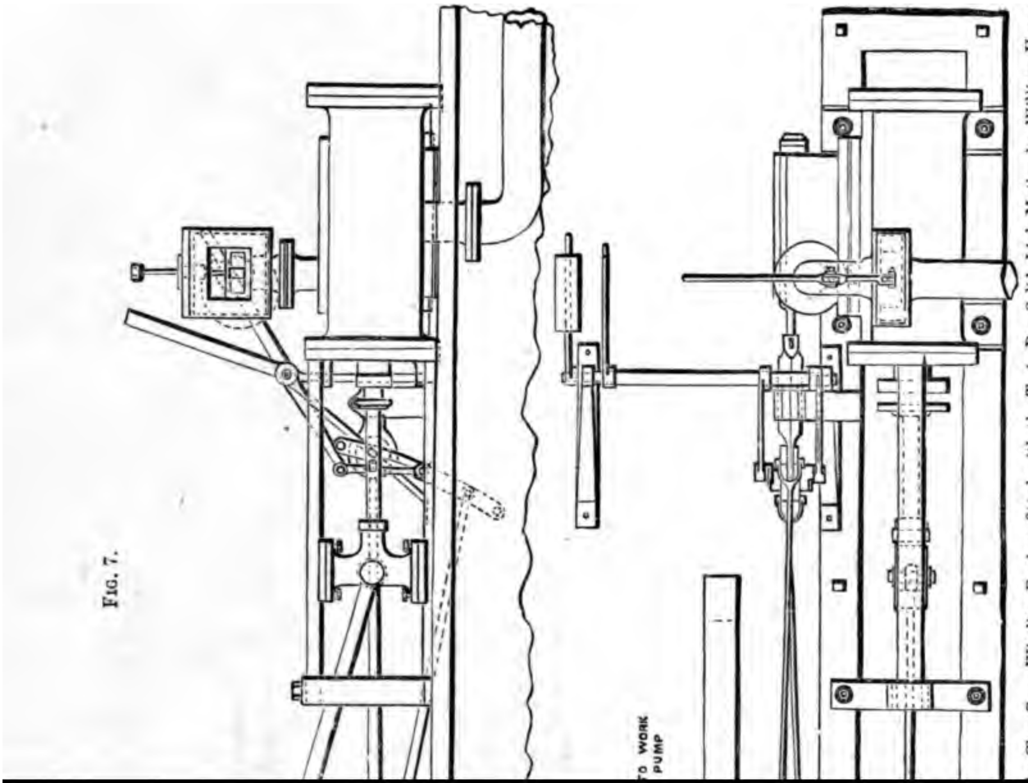
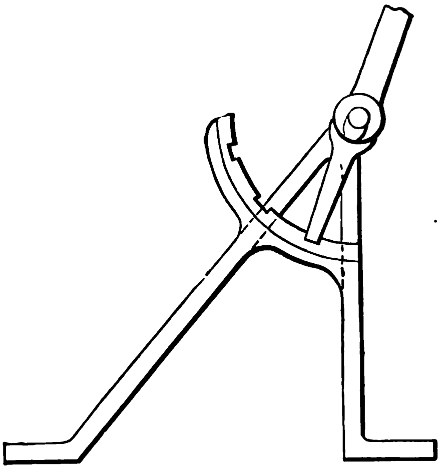


FIG. 7.

he Clay Cross Winding Engine, fitted with the Twin-Bar Solid Link-Motion by William Howe, the Inventor, in the year 1847.

link has been preserved. It was shown to Mr. Robert Stephenson, who highly approved of it, and desired William Howe to send it to the works at Newcastle. On receiving the model there, Mr. Weallens wrote to William Howe, also approving of the mechanical arrangement, and said he had shown it to Mr. Hutchinson, the manager, and Mr. Fletcher, of the North-Eastern Railway, and other men of mechanical science, all of whom agreed with Mr. Stephenson that the improvement was particularly advantageous over the solid block.

FIG. 8.



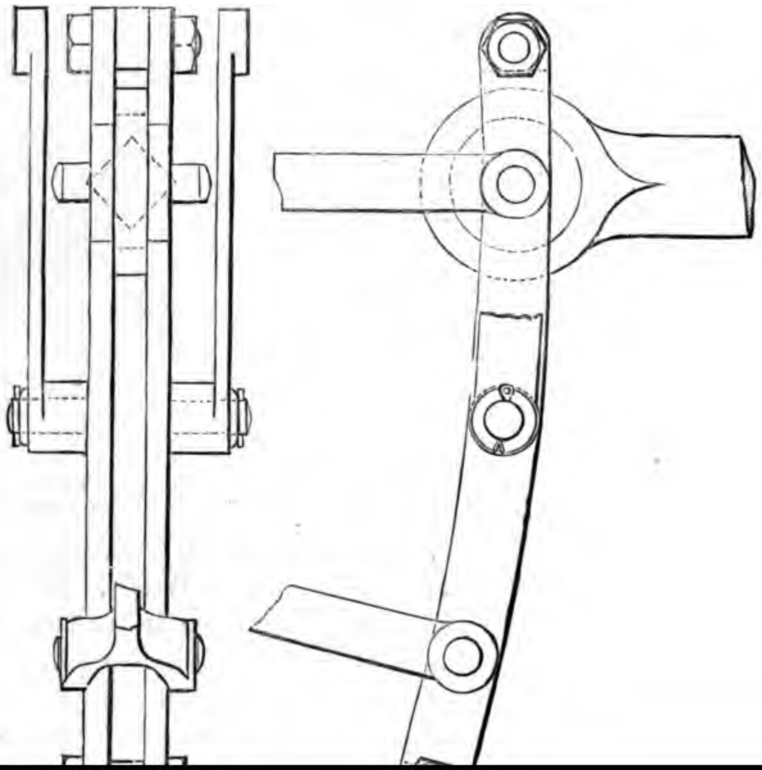
Detail of the Starting Gear of the Engine shown by Fig. 7, scale 1½ = 1 foot.

In the year 1854 Mr. Howe further designed another modification of his solid bar link, as shown by Fig. 12 in end and side elevation and sectional plan on page 13. This was applied to a large winding engine erected at the Clay Cross Works. The cylinder is 36 inches diameter, and 6 feet stroke of piston; it has been in constant work ever since, with perfect satisfaction, without repair or alteration, although the engine has been raising from 300 tons to 800 tons of coals and materials per diem up a shaft more than 200 yards deep.

It became essential in the year 1864 that the Clay Cross Company should extend their works, and it devolved on William Howe, their engineer, to design suitable engines to raise from a depth of 300 yards a certain quantity of coals and materials, for which he designed the arrangement shown by Fig. 13 on page 14, which is a side elevation and plan of a modification of Allan's straight link-motion applied by William Howe with much success.

The working gear of this engine is shown in plan and elevation by Fig. 14 on page 15, to which he applied the principle of Melling's valve gear, as described in this work on page 13, and illustrated by Fig. 10 on page 12. The eccentrics are fixed on a counter shaft that is driven by a pin passing through a drag link, receiving its motion from the connecting

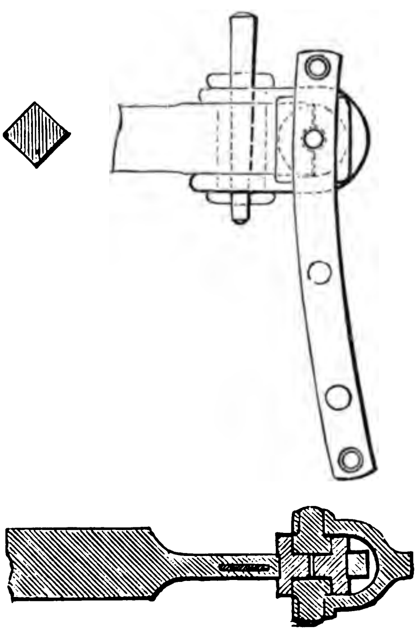
Fig. 9.



counter crank, *e*, *e* are the eccentrics, *m* the drag link worked by the pin or stud on the connecting rod, situated 4 feet from the main crank pin; *f* is the straight link, and *g* the reversing shaft, *h* the crosshead, *i* the guide rod, *l* the reversing rod leading from the link to the valve rod guide, *k* the piston rod, and *n* is the reversing handle. The cylinders of these engines are 30 inches in diameter with a piston stroke of 5 feet, the valves are the ordinary balanced slide valves, with ½ inch outside lap; the area of the full supply steam opening being $\frac{1}{18}$ of that of the cylinder, and the engines with the gear referred to were under perfect control when raising 36 cwt. of coal 300 yards in thirty-five seconds.

Subsequently to the erection of those engines, William Howe applied the same arrangements of valve gearing to another engine at the Coton Bank Collieries, near Burton-on-Trent, and since that to a similar pair of engines at the Clay Cross Works, the only difference being that the valves of the latter engines have 1 inch outside lap, which is more economical for the use of the steam, but is not so powerful in speed; and the high speed is of more importance with winding engines than a slight saving of fuel.

FIG. 10.

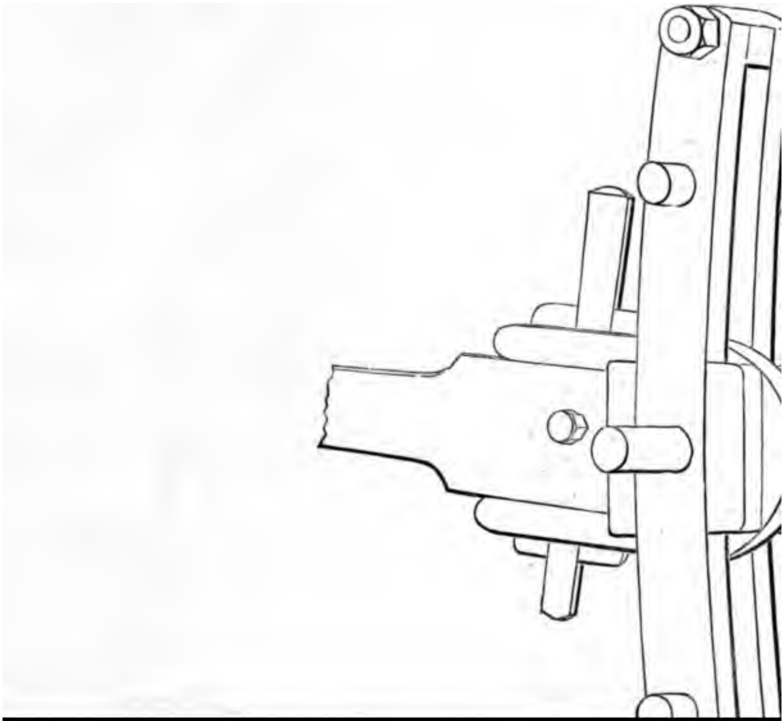


Adjustable Head and Block for the Twin-Bar Link-Motion, invented by William Howe in 1848.

It is now undoubtedly proved that Mr. Howe not only invented the common link-motion, but also that he improved his original ideas to a considerable extent at an early period; and also that to the engineering world he conferred a lasting benefit, where the steam-engine is used. That he fully understands the principles of his invention will be understood from the diagrams on page 16, which he has sent the author.

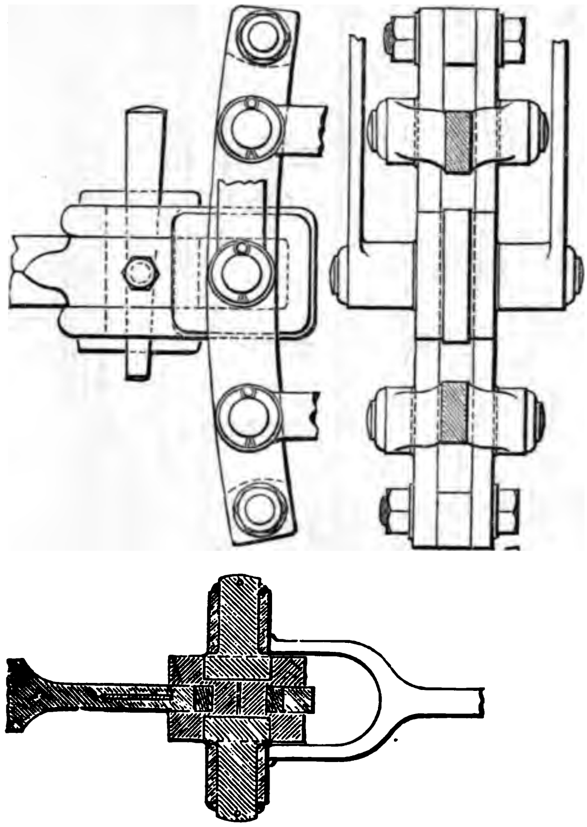
Figs. 15 and 16 are skeleton diagrams of a link-
crank, and pin, showing an equal lead for the slid
of the piston stroke. Figs. 17 and 18 illustrate tl

FIG. 11.



are not crossed in the first case, and the crank rising, but in the second are crossed and the crank working downwards, the angles of the eccentrics being the same in each case. It may be added that the alteration of lead in both instances is reduced as the length of the eccentric rod is increased, and *vice versâ*; a fact that must always be considered with the link motion.

FIG. 12.



Elevations and Sectional Plan of Howe's Improved Adjustable Head and Block, Link-Motion, applied to a Winding Engine in the year 1854.

This motion has been used since the year 1842 by all makers of steam engines for locomotive, marine, and stationary purposes, of all

classes and sizes, which, without it, could not hav
as they have, for there is no other valve gear it

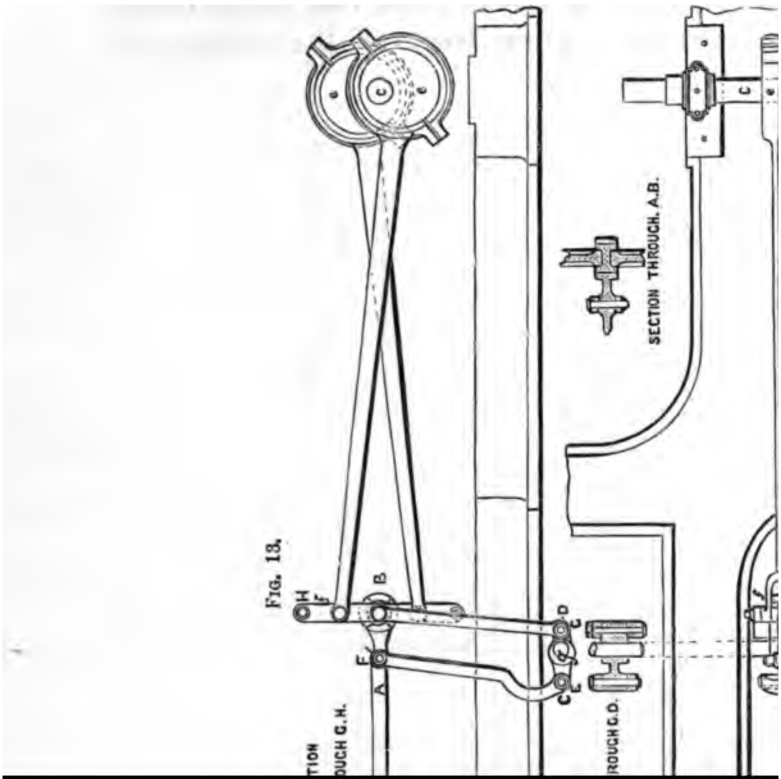


Fig. 13.

although, as we shall show in the second chapter, that divers inventions before and since have been proposed, patented, constructed, and applied for the very object of dispensing with it, if possible.

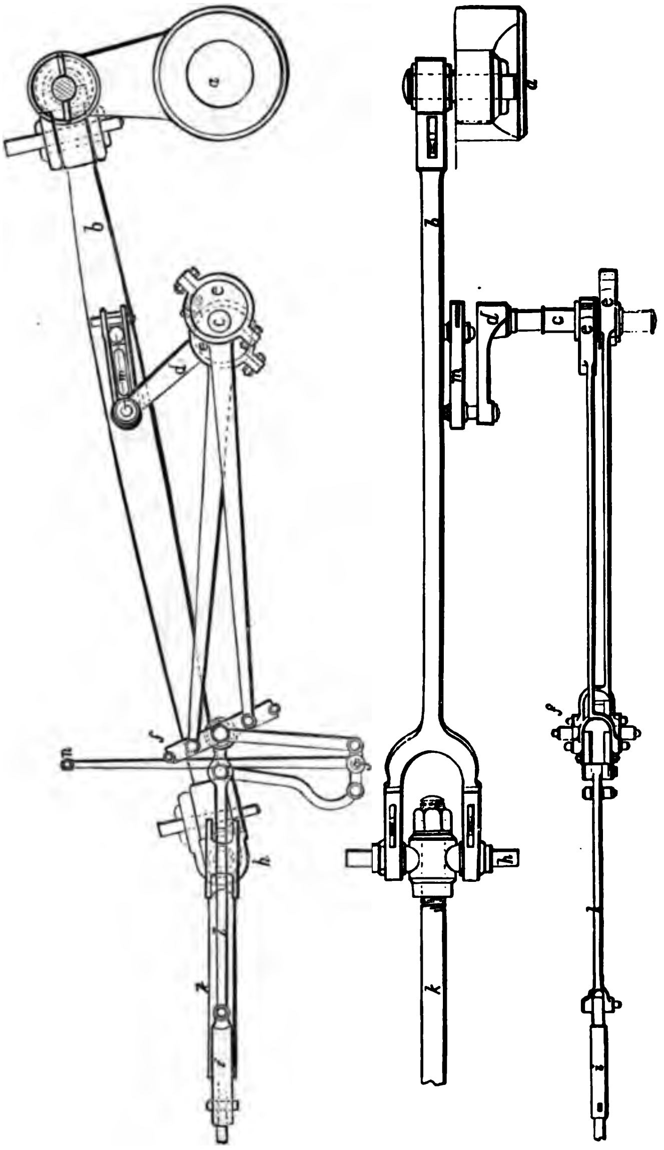
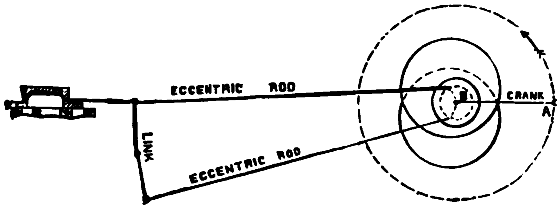


FIG. 14.

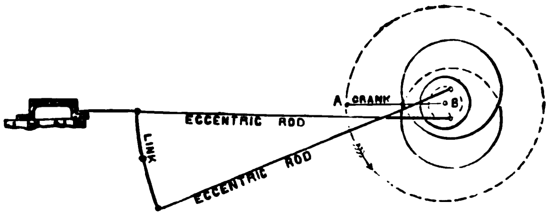
Working Gear of the Link-Motion shown by Fig. 13.

FIG. 15.



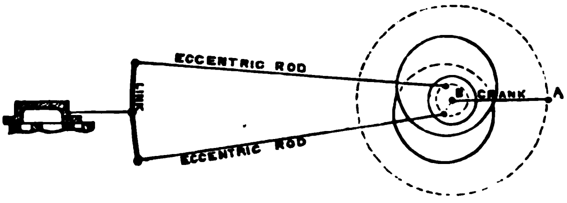
Howe's Skeleton Diagram of Link-Motion when the Link is down and the Crank out from the Valve; when the latter gives lead for the Steam.

FIG. 16.



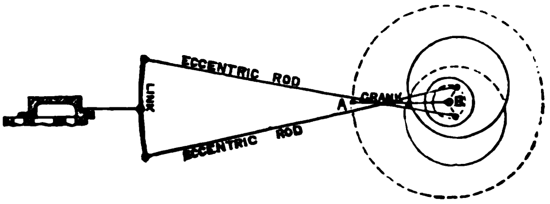
Howe's Skeleton Diagram of Link-Motion when the Link is down and the Crank is in towards the Valve; when the latter gives lead for the Steam.

FIG. 17.



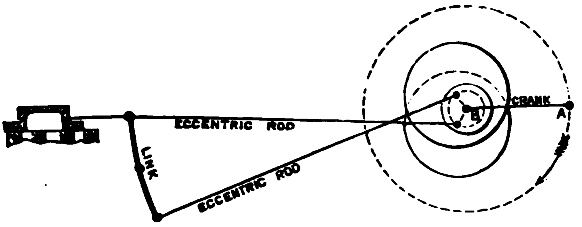
Howe's Skeleton Diagram of Link-Motion when the Link is midway and the Crank out from the Valve.

FIG. 18.



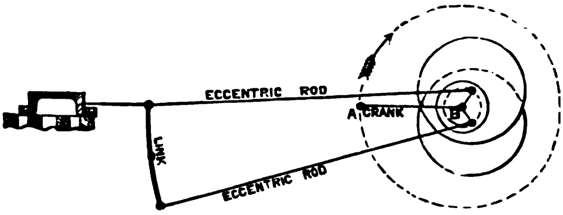
Howe's Skeleton Diagram of Link-Motion when the Link is midway and the Crank in towards the Valve.

FIG. 19.



Howe's Diagram, showing the Eccentric Rods crossed, instead of as in Fig. 15, but the position of the Crank and the Lead being, as before,

FIG. 20.



Howe's Diagram, showing the Eccentric Rods not crossed, instead o as in Fig. 16, but the position of the Crank and the Lead being, as

LINK-MOTION

AND

EXPANSION-GEAR.

CHAPTER I.

THE PRINCIPLES OF THE ACTION OF STEAM-WORKING VALVES.

THE regulation of steam, in its application as a motive power, is of the utmost importance; and it is for that reason that all engineers who design and construct steam-valves and their motion-gear, should consider first the requirements that are subject to the purpose, and secondly, the *most* simple and effectual mechanical arrangement possible that can develop them. In order, therefore, to probe this matter properly, we must dilate first on the principles of the requirements, and after that discuss the means for the mechanical development.

The action of the steam in an engine-cylinder is designated under four headings, known as "lead, cut-off, expansion, and exhaustion," which are the principles of the requirements on which the arrangement of the valve and gear depends.

LEAD.—This is practically a certain quantity of steam that is admitted between the piston and the cylinder end, when the former is moving towards the latter, and thereby checks the momentum of the piston at each end of its stroke or travel, and prevents it from straining the piston and connecting rods, and disturbing the centres of the true positions of the crank-pin and shaft. The position of the valve to cause lead, is that it uncovers the steam-port, or opens the passage for the admission of the steam into the cylinder, before the piston completes its travel or stroke. So that the situation of the valve relative to its travel is said to be in advance of that of the piston under the same circumstance of relation. The valve, therefore, has performed the greatest portion of its limit of motion in one direction before the piston has commenced the similar movement. Now the *time* allowed for lead will depend on the advance position of the valve, and as time is subjected to motion in this case, the relation of one to the other must be constant; therefore, if we have lead for a high-speed engine, and the valve-gear is arranged for that purpose, we shall have the lead constant with a lesser speed, because—although time is subject to valve-speed—travel is subject to gear-motion, and if the lead is required to be altering with the speed, then the gear must be in connection with the engine-governor.

Cut-off.—The quantity of steam that is admitted during the limits of lead and cut-off is the "supply;" hence it is evident that the amount of supply is subject to the time allowed between the lead and cut-off, for the admission of the steam.

Now let us put this matter graphically, for the purpose of demonstrating the actual meaning of the facts in practice. Suppose we are looking at an engine-cylinder, and can see the internal details in it, we notice that when the piston has reached *nearly* to the end of the cylinder, steam is admitted into it by the valve, and thus the speed of the piston is the action. When the piston had moved for a certain distance from the end of its travel, the area of the supply opening began to be decreased by the valve passing slowly over the port, and continually decreasing its opening until the port was covered by the valve. Now the powerful effect of steam is in direct proportion to its quantity—pressure being excepted—and, therefore, when the valve began to reduce the area of the steam supply opening, the power was reduced from that moment, and gradually reducing also to the time of cut-off, so that with a gradual cut-off, the efficiency of the steam is lessened *from the beginning* of the action of cut-off to the stoppage of the admission.

Let us now watch the action with a sudden cut-off. The piston is advancing as before from the end of the stroke, the supply of the steam being constant and the quantity in the cylinder increasing; at a certain point the valve closes at once, the admission of steam is stopped, but as the supply was equal during the beginning of the motion of the piston to the point of cut-off, the power was equal also, and therefore no reduction ensued, as with the slow motion for the valve.

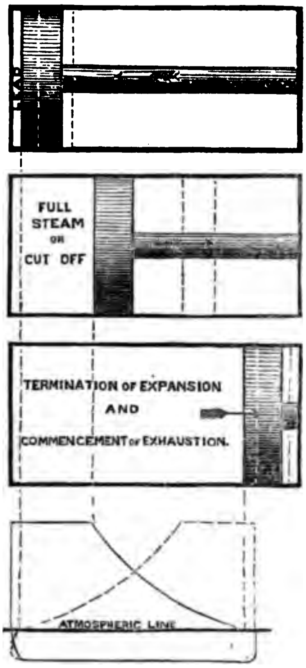
EXPANSION.—The steam that has been admitted into the cylinder is now supposed to be cut-off from that proceeding from the boiler, and our attention must be directed next to what it performs; for it is now a power without any assistance whatever, and indeed so self-reliant that all the energy it expends diminishes the original possessive power proportionately. This reduction of power is due to the piston being impelled by the *expansive* action of the steam situated between the cylinder end and the piston—including that in the steam passages leading to the valve.

Here then we have a volume of steam exerting *all* its efforts to burst the cylinder, and as it does not do that, it pushes the piston onwards, but without any assistance whatever from the steam that is in the boiler; hence the power of the engine for a period, originates from the *elasticity* of the steam, the action of which in the cylinder is practically as a steel spring that has been compressed, and on releasing it, all the power—excepting that absorbed by friction—that has compressed it, is given out again by the spring's exertion to expand itself to its natural limit of extension.

This is an analogous definition of the expansion of steam, and our next purpose is to describe how the original power is reduced proportionately to the limit of expansion. The reduction of the original power of the steam by expansion is due to one cause theoretically, but to two practically, in this way: the steam is said to be reduced theoretically in pressure, or power, proportionate to its cubical expansion; as for example, suppose a volume of steam at 60 lbs. per square inch pressure occupied *one* cubic foot, and it is permitted to expand into *two* cubic feet, the pressure will be reduced to 30 lbs., and so on in a similar proportion; but in practice this reduction of pressure is more than quoted; and the two practical causes alluded to are radiation and friction of the steam that produce it, so that the loss in practice below theory is equal to from 10 to 15 per cent. The friction is constant due to the pressure, but the radiation is less or more as the cylinder casings and steam supply pipes are covered or not.

Exhaustion.—The steam is now presumed to have performed all its duty in the cylinder, and is being released to expand into the atmosphere or be condensed into its normal condition in the condenser. The action of the exhaustion should be as quick as possible, but unless the slide valve and ports are suitably arranged, the process is checked or slowest at the commencement instead of being the quickest; in fact, piston moves; in rushes the steam after it, and continues to fill the space in the cylinder with equal pressure until the valve suddenly closes the port; "the cut-off" here occurs and also at this point "expansion" begins. The piston is now, say at one one-third of its travel, and the crank and connecting-rod at the relative angles. The steam drives the piston before it, and as the crank-pin is now traversing the portion of its travel that is most coincident with that of the piston, the momentum is at its utmost limit of power. At, say about seven-eighths of the piston's travel, the valve uncovers the exhaust port; away rushes the steam from its duty in the cylinder and leaves the piston to itself; and here happily the momentum left in the crank-pin is transmitted to the piston, which carries it on to the end of the stroke. The crank and connecting rod are now on the level line again in the opposite direction to that before; and the "lead" occurs again also at the opposite end of the cylinder.

FIG. 1.



Diagrams of the positions of the piston of an engine, at occurrence of "lead, cut-off, expansion, and exhaustion," with the corresponding indicator diagrams.

The principles of the correct method of regulating the use of the steam in engines is therefore *ample* "lead" in proportion to the speed of the piston; *instantaneous* "cut-off;" *maximum* "expansion;" and *immediately total* "exhaustion" during each stroke of the piston. To make this matter perfectly understood we illustrate by Fig. 1 the limits of the inside lines of a cylinder, with the piston in three positions, and an indicator diagram whose limits agree with them. The return positions are shown by dotted lines, also the relative indicator diagram. These diagrams are *perfect*, and demonstrate a similar arrangement of gear and valves; this is theory, however, and we will now turn to the practice and see the width of the disagreement.

CHAPTER II.

THE HISTORY OF THE PRACTICAL APPLICATION OF VALVE-GEARING.

THE most reliable history of the original adoption of valve-gear in steam engines has been written by a Doctor Desaguliers, who not only was an eminent philosopher, but also a practical machinist, and in his courses of "Experimental Philosophy," dated 1744, he states :—

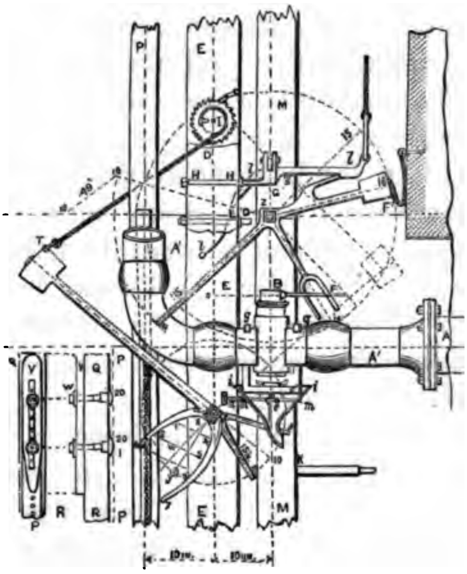
"About the year 1710, Thomas Newcomen, ironmonger, and John Cawley, glazier, of Dartmouth, in the county of Southampton, made then several experiments with the steam-engine in private, and having brought it to work with a piston, &c., in the latter end of the year 1711, made proposals to draw the water at Griff in Warwickshire; but their invention meeting with no reception, in March following, through the acquaintance of Mr. Potter of Bromsgrove, in Worcestershire, they

they had always done it on the outside. They used before to work with a buoy in the cylinder inclosed in a pipe, which buoy rose when the steam was strong, and opened the injection-pipe and made a stroke, whereby they were capable of only giving six, eight, or ten strokes in a minute, till a boy named Humphrey Potter, who attended the engine, added what he called *scoggan, by which the beam of the engine always opened and shut its own valves,* and then it would go—entirely without the attendance of a man—fifteen or sixteen strokes in a minute. But this being perplexed with catches and strings, Mr Henry Beighton, in an engine he had built at Newcastle-on-Tyne in 1718, took them all away, *the beam itself supplying all much better.*"

So that from that date self-acting valve-gear for steam-engines was adopted, and, although in a crude state, performed its duty with precision sufficient enough to be adopted for regulating the supply of the injection-water also; and consisted of an arrangement of levers and catches that opened the steam-valves and injection-cock by the levers being raised and lowered by tappets on the working-rod, which was descending or hung from the beam of the engine. The entire affair was of course of the primitive order, and therefore very defective.

In the year 1769, Mr. Smeaton made a beam, single acting, steam-engine with the valve-gear arranged pretty much as Beighton's, and in the year 1775 another engine with improved valve-gear, which we illustrate by Fig. 2, the description of which is as follows:—

FIG. 2.



Front elevation of Smeaton's Valve-gear for his single-acting Steam Beam-Engine of 150 nominal horse-power, made in the year 1775.

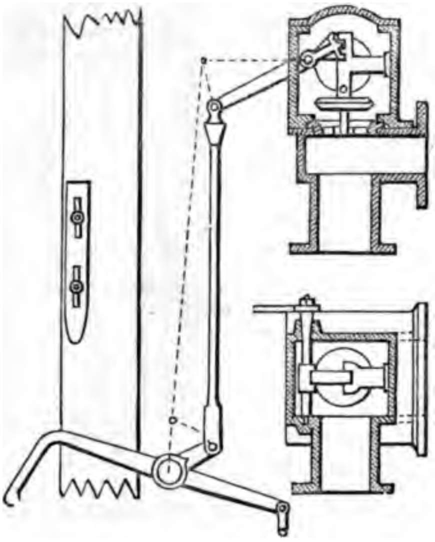
"A is the lower corner of the

cylinder, A A′ A′, the injection-pipe, B, the injection-cock, B F, its handle or spanner passing between the forks of the bent lever E Z F F′, called the F lever, by which the cock is opened and shut. The tail Z 12 of this F lever is, by the downward motion of the plug-tree P, forced from the position shown by the dotted line Z 18, into the position in which it is seen in the drawing, and it is there retained by the catch *l l l*. While the lever is in this position the injection-cock is shut, the steam from the boiler is flowing into the cylinder, and the piston is rising. When the piston has nearly reached the top of its course, an apparatus attached to the plug-frame P, draws up the catch *l l l*, and releases the F lever, which is forced into the position 18 Z, by the bob or weight 16, carried by its end F′, and the consequent movement of its fork F opens the injection-cock; T *x* 11, 9, is the Y lever or tumbler, which acts upon the stirrup rod *k* attached to the spanner of the regulator, as in Beighton's gear. The range of the tumbler's motion on each side of the perpendicular is regulated by its check-cord T I, which is passed round a roller I, furnished with a paul and ratchet, so that its length may be adjusted. The tumbler is moved by pins in the plug-frame P, acting upon its bent arms *x* 3, *x* 7.

"In the left-hand corner at the bottom of the illustration is seen a representation of a slider, which may be fixed upon the plug-tree instead of the pins, to work the lever. There is both a side and a front

The memorable James Watt, in the year 1788, made a vast improvement on Smeaton's engine, by making it double-acting, and the valve-gear is shown by Fig. 3, which is a drawing of one of the valves and its working gear, also a part of the air-pump rod, formed of wood, called the plug-frame or plug-tree, on which are two projecting plugs of wood to work the upper and lower valves. As the plug-tree moves up and down, the plugs strike the handles or working gear of the valves, and open or shut them at the proper instant. The valves are called conical valves, because the small cover which closes the opening of each nozzle under the valve is slightly tapered downwards so as the more readily to fit its seat, and each is lifted from its seat by a small toothed rack and pinion moved by a spindle from without, communicating by rods with the valve gear. When the plug-frame descends, the valve is closed by the plug, and the valve is shut.

FIG. 3.

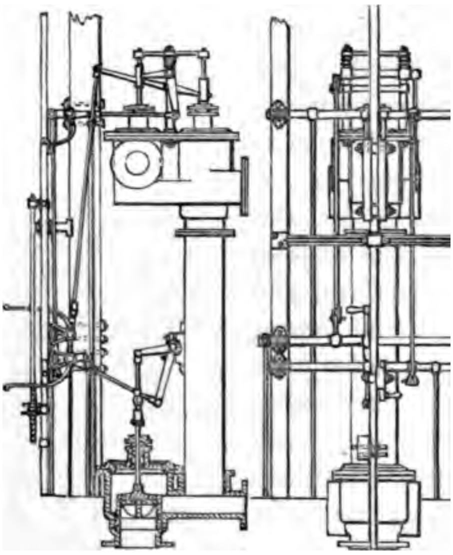


Side elevation of Watt's Valve-gear, and sections of Valve and Seating for his double-acting Steam Beam-Engine, made in the year 1788.

Mr. Murdock, Mr. Watt's assistant, very much improved the valve-gear for beam steam-engines—over Mr. Watt's arrangement as shown by Fig. 3, above—and the result of his labours was the now well-known "Cornish" valve-gear, as shown in side and end elevations by Fig. 4, which was introduced as far back as 1820, and of course has been improved in detail since, which we shall notice, but the main portion is even now as at the date mentioned. Soon after that time the vertical direct acting engine came into use, and with it the cam and eccentric motion for working the *slide* valve. Next was introduced the

horizontal engine, with the valve-gear of the for
same purpose.

FIG. 4.



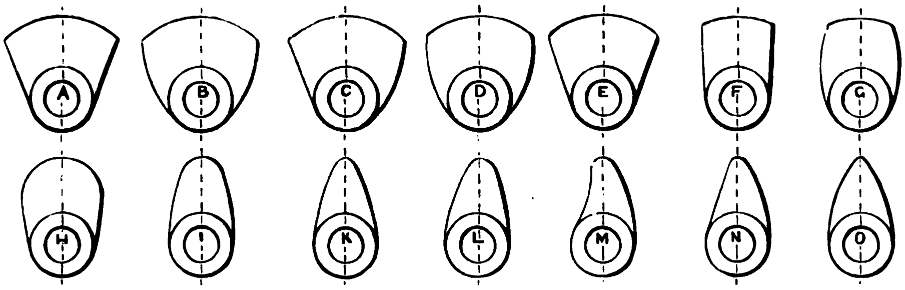
Side and End elevations of the Valves and Gear, as fit
the Cornish Steam Beam-Engines in the year 182

A drawing of the original cam and frame is sho
are shown in three positions: first, cam at full stro

FIG. 5.

the introduction of those, cams were made of almost every conceivable shape, as illustrated by Fig. 6.

Fig. 6.



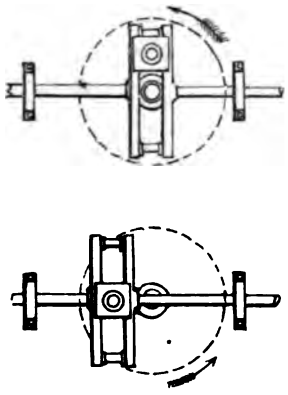
End elevations of a series of Cams for imparting motions to the Valves of Steam Engines as used from the year 1821 to the year 1870.

A. Broad Cam with straight sides.
B. „ „ with curved sides.
C. „ „ with straight and curved sides.
D. „ „ curved sides and round corners.
E. „ „ straight sides and round corners.
F. Narrow Cam with parallel straight sides.
G. „ „ with curved sides.

H. Narrow Cam, with semicircular driving edge.
I. „ „ with elliptical driving edge.
K. „ „ with elliptical driving edge.
L. „ „ with uneven sides.
M. „ „ with concave and convex sides.
N. „ „ with convex and straight sides.
O. „ „ pointed.

Next came the gear, as shown by Fig. 7, which imparted a reciprocal but constant motion to the rod, whereas the cam permits the rod to be *still* for a period, the time of which is proportionate to the form of the driving part of the cam. This gear is used in the present day for donkey-engine pumps.

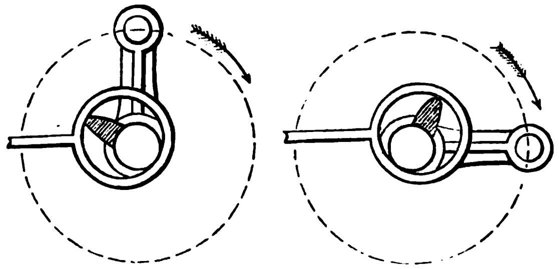
Fig. 7.



Crank-pin and Stop-valve Gear, introduced in the year 1820.

Following that, the eccentric band and cam were used, as depicted by Fig. 8, which is

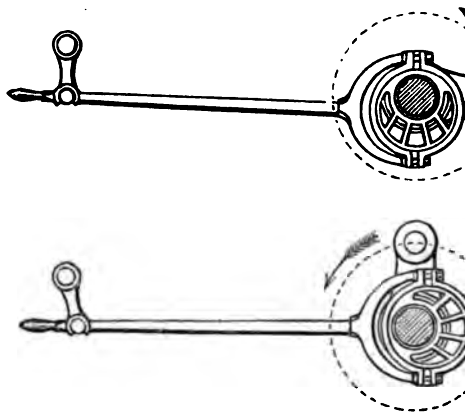
Fig. 8.



Narrow Cam and Ring Valve Gear, introduced in the year 1820.

merely a cam of the narrow order enclosed in a rangement was the beginning of the eccentric mc as illustrated by Fig. 9.

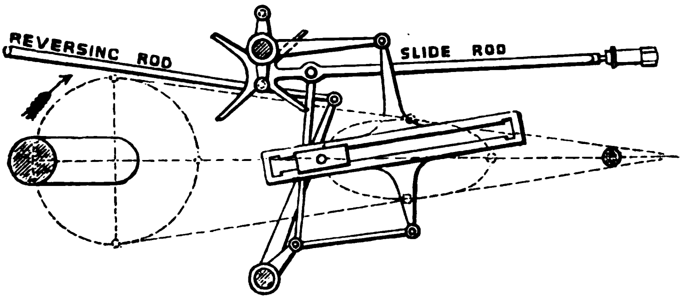
FIG. 9.



Eccentric-Motion for Valve-Gear, introduced in the year

This was really a great improvement over the c it was practically applicable for quick speed engines, motion is *not*; but even with that attainment the not content, for in the year 1830, Mr. Melling, t superintendent of the Liverpool and Manchester ra form of valve-gear as illustrated by Fig. 10; for l the leading railway engineers. Mr. Melling considered that he could supersede the eccentric by putting a stud midway of the length of the connecting-rod, and attach thereto a slotted end lever, by which connection a slip of the connecting rod's motion would reduce the travel of the other end of the lever sufficiently for what was required for working the slide valve as shown. It will be noticed also that the centre of the stud describes an ellipse, and we may explain, too, that the motion imparted to the valve by this arrangement is the slowest when it should be the quickest, such as for "supply steam" and "cut-off," hence it was never universally adopted. That fact, however, did not prevent Mr. Hawthorn, in the year 1838, from introducing his arrangement, as illustrated by Fig. 11, which is similar to Melling's, the connecting-rod having a stud in it, and the working lever being slotted where attached thereto.

FIG. 11.

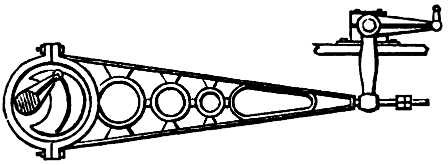


Hawthorn's Slotted Lever and Connecting-rod motion for Valve-Gear for Locomotive Engines, invented in the year 1838.

We here pause in our systematic historical travel, and direct the reader's attention to the fact that, when the locomotive engine was introduced in the year 1820, the "cam and frame" were previously adopted for the valve-gear; but as those were of no use for reversing, a *loose* eccentric and band were invented, as shown by

Fig. 12. A Mr. Wood did this, the engineer of the Killingworth engine factory.

FIG. 12.



Side elevation of the Killingworth Locomotive Engine Valve-Gear, being loose Eccentric and fixed Stops for reversing, used from 1820 to 1830.

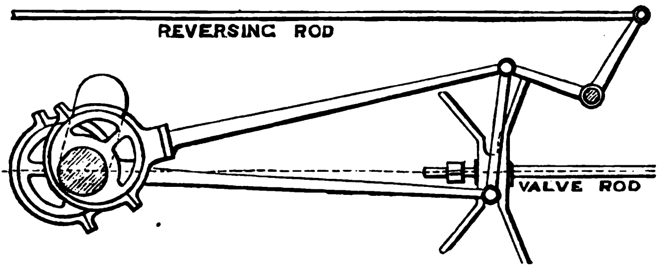
Mr. D. K. Clark, in his excellent—and, indeed, the only reliable—work on the locomotive engine, decribes this gear thus : " A lever was fixed upon and revolved with the driving axle formed with a stud which entered and slid freely in a concentric groove cut in the body of the eccentric. The stud found its way to one end of the groove and determined the position of the eccentric on the shaft for tho fore or back gear. The small end of the eccentric rod was permitted some longitudinal play in the eye of the intermediate lever—adjustable by nuts."

We here remark that this method of permitting the eccentric to *slip* for a certain length of arc on the shaft is precisely as that adopted in the present day by marine engineers for the "single eccentric" reversing gear for oscillating paddle-wheel engines.

After the adoption of the loose eccentric in 1820, Mr. Clark in his work informs his readers that gabs or levers were adopted on the end of the eccentric rods to impart proper motion to the levers in connection with the valve rods, and many arrangements were proposed for that purpose

Watt did. The slide valve applied had *no* lap, so to speak, for it only covered the outer edges of the supply ports, $\frac{1}{16}$th of an inch, when at half stroke. *Wide* bars were cast between the supply and exhaust ports, and the valve had no proportion relative to its duty, so the result was, that the admission of steam occurred for nearly the entire stroke of the piston, and its expansion was only momentarily, while the exhaustion *began* when the piston completed its stroke, and *finished* after the return travel was a good way entered on.

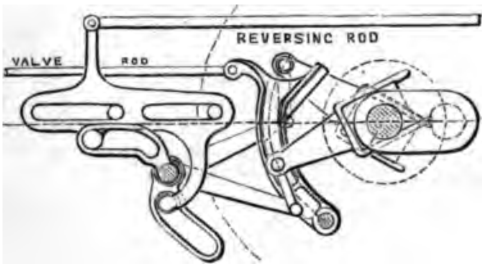
FIG. 13.



Stephenson's Gab and lever Valve-Gear for Locomotive Engines, for reversing with two Eccentrics, applied in the year 1840.

That way of regulating the steam was of course the *worst* possible, and if the engineers in question had tried their utmost to have exceeded the evil by any other means they could not have done it so successfully. Their knowledge, therefore, of the actual properties of steam must have been very vague, so much so indeed that they were using it without any discrimination. The only fact apparent to them must have been, that the steam when it got into the cylinder must be allowed to escape from it, and thus their aim was accomplished by the valve alluded to as used in the year 1838. At that date the engineers were put to their wits' ends how to reduce the consumption of the fuel, for that matter made a great hole in the profits of railway management; and the result was that the slide valves were after then, made with an outside lap of from $\frac{1}{4}$th to $\frac{3}{4}$th of an inch, varying by $\frac{1}{16}$th and $\frac{1}{8}$th, when in the year 1840 *one* inch lap was adopted. And thus nearly one-half the fuel was saved because one half the steam was used, and time and area permitted for its expansion and exhaustion. The locomotive engineer was not, however, content with outside lap for the valve only, for even before the last date quoted, or in 1839, Mr. John Gray applied his invention of expansion-gear, as shown by Fig. 14, to the "Cyclops" locomotive engine on the Liverpool and Manchester railway, which produced an economy of fuel amounting to 12 per cent. over the other engines then in use.

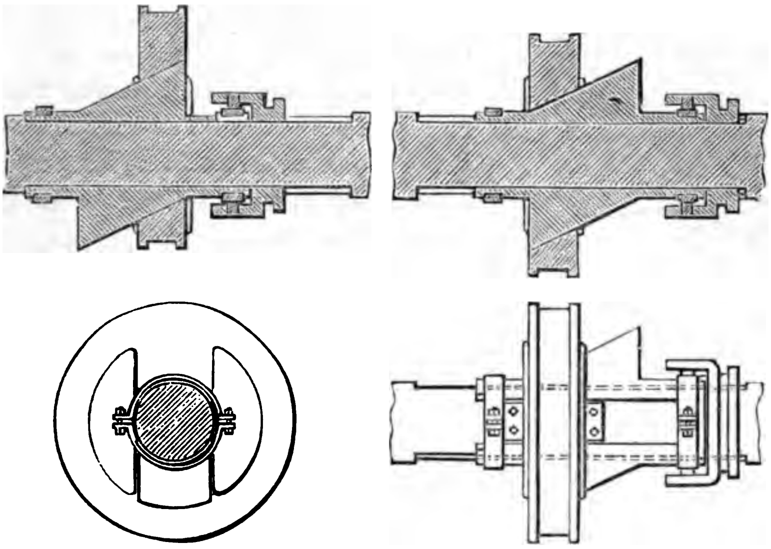
FIG. 14.



Gray's Slotted-Valve-Gear for Locomotive Engines, for altering the Grade of expansion, practically applied in the year 1839.

Mr. Clark in his work describes this gear as follows: "The pin of the eccentric rod works in a segmental lever curved to the radius of the rod, the upper end of which is linked to the valve spindle. Thus the lever, being concentric with the fore rod at the beginning of the stroke, the rod can be raised or lowered in the slope of the lever to any required distance from the fulcrum, which of course regulates the travel of the valve while the lead remains unchanged. The reversing mechanism consists principally of a wrought iron frame which slides horizontally on two fixed pivots and carries rollers, which, working in grooved levers linked to the eccentric rods, places these rods in and out of gear with the segmental [redacted] eccentrics sliding laterally on the shafts, but allowing them to move between these ears transversely. The parts which move the eccentrics

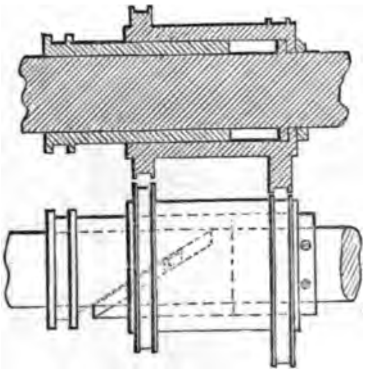
FIG. 15.



Dodd's "Wedge-Motion" for shifting the eccentrics, to alter the cut-off and reversing, invented in the year 1839.

more or less from the centre of the shaft, are inclined planes or wedge-shaped pieces sliding laterally upon the shaft, and passed through slots or openings in the eccentrics, so that as they are forced through them they shall change the relative positions of the centres of the eccentrics and shaft. These wedge-shaped pieces are securely connected to the shaft by keys working in long slots, to prevent the inclined planes slipping round upon the shaft, consequently they are made to revolve with it, and by passing through slots in the eccentrics also cause them to revolve with the shaft. The inclined planes or wedges are connected to a clutch box moved by a forked lever, used to slide them laterally to and fro upon the shaft without interrupting their rotatory motion. Dodd and Owen proposed also at the same period another method, as

FIG. 16.

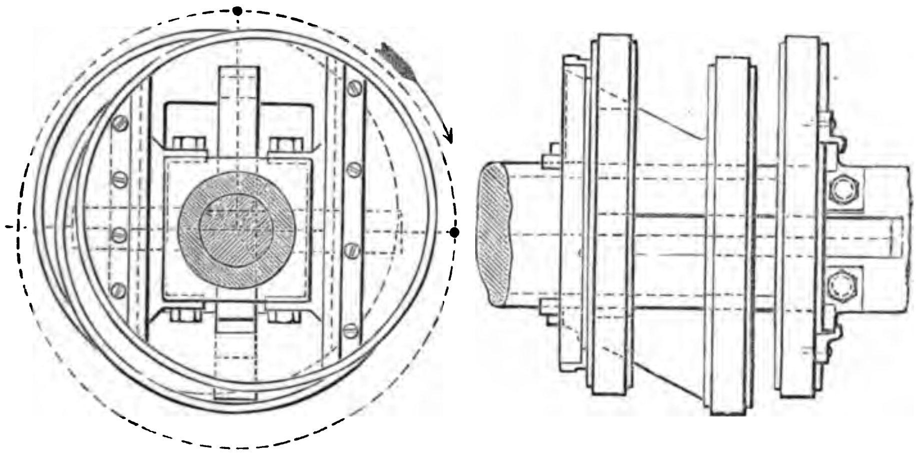


Dodd's Slot and Wedge-Motion for Shifting the eccentrics, and alter the cut-off and reversing, invented in the year 1839.

illustrated by Fig. 16, in two views, sectional a
mechanism is also mounted on the rotatory shaft,
eccentrics belonging to the valve motion so as to cl
It consists of an inne
embracing the shaft,
to slide laterally along
time partly around it,
an inside screw around
this tube or collar is f
or groove, and upon
tion of the curve of tl
movement of the ecce
is fixed a pin or s
into this groove; ai
ever the collar or tı
tudinally along the
cause it, by its connec
to move around the shaft. The eccentrics are
or outer, tube or barrel embracing the shaft
they may form the tube itself, but is prevente
nally by means of a fixed collar on the shaft
This outer tube or barrel is securely connected
means of a key or feather and a slot, capable of s

fixed in the inner tube, and by this arrangement of the parts the same effect will be produced. Both of those methods were soon after more practically arranged, as shown by Fig. 17, by Mr. Dubs, of Glasgow.

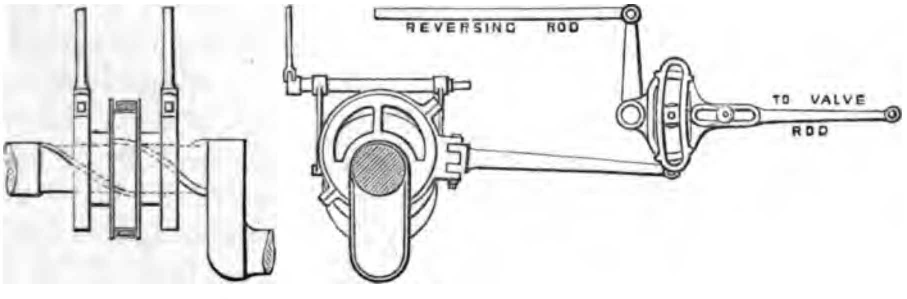
FIG. 17.



Dodd's Wedge-Motion as arranged by Dubs, in the year 1842.

The next approach to Dodd's gear is Fenton's, and that is shown in two views by Fig. 18, which is a combination of sliding eccentrics and link

FIG. 18.

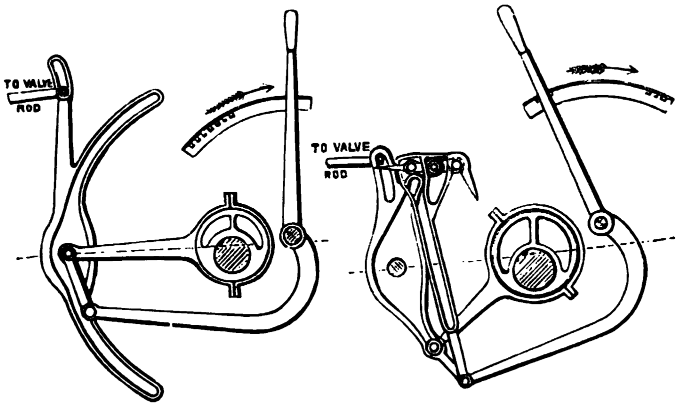


Fenton's Sliding-Eccentric Valve-Gear for Locomotive Engines, introduced in the year 1842.

motion. The eccentrics are fixed on the shaft by a spiral feather, which adjust them also to any angle for the grade of cut-off and lead. The link is hung on a fixed centre and the connecting rod of the valve rod is slotted as shown.

In the year 1842, Mr. Crampton, the then well-known locomotive engineer, invented, and patented his arrangement of link motion, as illustrated by Fig. 19. The left-hand arrangement shows the eccentric

FIG. 19.



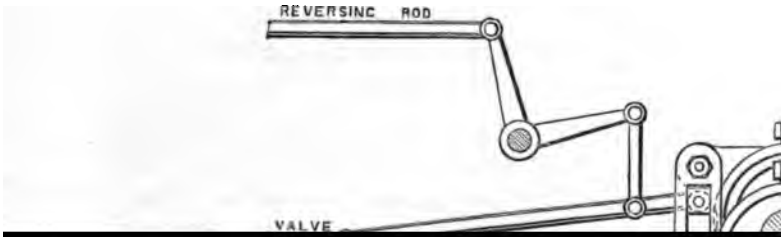
Crampton's Link Motion for Locomotive Engines for reversing, patented in the year 1842.

out of gear, during which, while in motion, the end of the eccentric rod works backwards and forwards in the widest or enlarged part of the groove on the lever, without causing the same to vibrate; but when the handle is shifted in the direction of the arrow to the first notch in degrees with the centre line. The valve will then cut off the steam at about one-third of the stroke of the piston. By fixing the handle at any of the intermediate notches, the cut-off of the steam will range between about seven-eighths and about one-third of the stroke of the piston. By moving the handle back in the opposite direction to the arrow to the first notch on the other end of the quadrant, the end of the eccentric rod will be forced into the lower end of the lever, and the action of the slide-valve reversed, the steam being cut-off at about seven-eighths of the stroke, as in the forward motion of the engine. The eccentric rod, when inclined at the angles mentioned, will only permit the steam to be cut off in the proportions mentioned when the end of the valve rod is at the lower end of the slot. When the end of the valve rod is raised, the angles formed by the eccentric rod must be increased a few degrees. The formation of the curve of the groove in the lever is struck from the centre of the eccentric at the time the piston is at either end of the stroke. The eccentric must be fixed on the axle with the full part at a right angle to the centre line drawn through the centre of the eccentric and the axis of the lever, when the piston is at one end of the stroke. The arrangement on the right hand shows that the end of the eccentric rod is at the bottom of the groove of the lever, and the end of the valve rod is at the top of the slot, level with the top of the fork or gib ends: the slide valve being arranged to cut off at about three-fourths of the stroke, and give about five-eighths of an inch lead of admission. The lead for admission may be diminished by shifting the handle of the lifting lever a small distance in the direction of the arrow, which will raise the end of the eccentric rod and the link, and lift the fork from the stud on the short end of the small lever, and allow the tail end of the small lever to fall by the weight of the end of the valve rod, in consequence of which the travel of the slot and valve will be diminished. The valve rod is made to lift more than the eccentric rod, in such proportion as not to alter the cut-off of the steam by the inclination of the eccentric rod. The eccentric is thrown out of gear by raising the end of the eccentric rod to the middle or enlarged part of

the groove on the lever, by forcing the handle t
middle of the quadrant. The engine is reversed l
to the opposite end of the quadrant, which rai
eccentric rod to the top of the groove in the lev
time raises the link, and the tail end of the
sequence of the stud being lifted by the bottom of

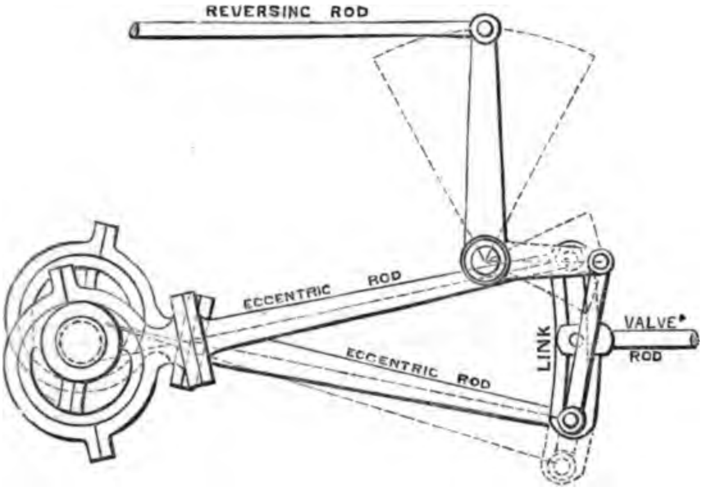
It is obvious that the principles of Gray's and
pretty much the same, and that, although the in
the same result, the mechanical contrivances wer
very complicated. Dodd's and Fenton's gear we
not at all simple or certain; they, of course, used
other two, but at the cost of imperfect action whic
by the link. Gray had first hit on an approxim
ments, and Crampton followed him, and he was t
Newcastle, who brought out the arrangement sho

Fig. 20.



the introduction of the now well-known "*Link-motion*," which was first invented by Mr. Howe of Newcastle in the year 1842, and in the year 1843 it was practically applied by Messrs. Robert Stephenson and Co., as illustrated by Fig. 21.

FIG. 21.



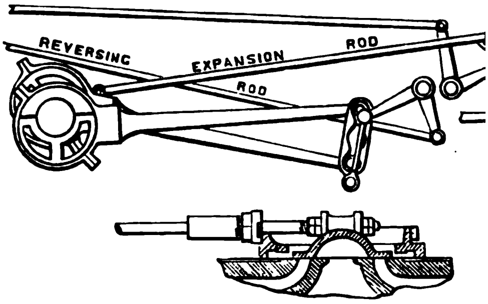
Howe-Stephenson's Link Motion for Locomotive Engines, applied in the year 1843.

It is really worth remarking here that all the prior inventors to that date must have worried themselves tremendously to have carried out their complicated arrangements; for their aim being vague was far short of the requirements for perfection of result, as much as their mechanical contrivances involved almost every conceivable complication possible; so that the little they understood about the regulation of steam in the engine cylinder was developed in the most adverse way for success. Indeed they must have forgotten that "wear and tear," as the phrase goes to express friction and the reduction of the strength of material, should always be considered primarily in relation to the efficiency of any mechanism, and in no case more so than the valve-gear of the steam-engine.

But to return again to our historical duties: in the year 1843, Mr.

Hawthorn, of Newcastle, improved on the arrange
1838, as shown by Fig. 11 on page 13, and paten
illustrated by Fig. 22. The peculiarities of this

FIG. 22.



Hawthorn's combined Link-Motion and Expansion Gear fo
Engines for two Slide Valves, patented in the year 1

whereas steam had been heretofore used expansi
well as other steam-engines, but in the case of
paratively small advantage; for though by varyi
slide valve the steam is cut off at various portion
piston, yet at the same time the passages for the
the steam are constantly being changed, so that
results from that mode of expansion. And wherea

until cut off, and may be cut off almost instantaneously at any portion of the stroke of the piston.

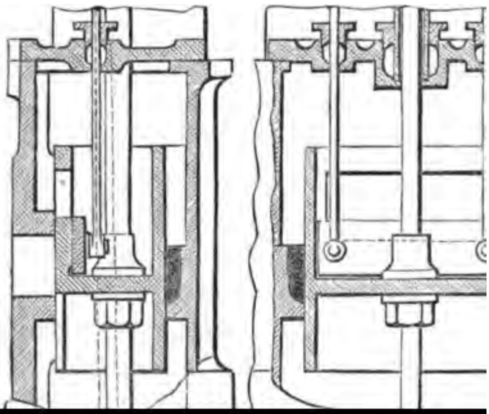
The ordinary slide valve is placed in a horizontal position, and worked directly from the driving axle by two ordinary eccentrics. The coupling link is of a peculiar form, which is contrived to diminish as much as possible the friction and wear upon the slotted ends of the eccentric rods and the connecting pin; the wide space in the middle part of the link allows the eccentric rods to work without moving the slide valve, so that the valve is constantly at rest, and closely shuts the ports when out of gear. The auxiliary expansion slide frame is fitted to and works upon the same surface or face as the main slide valve. There are projections on the inside of the expansion slide frame, so that when the frame is in motion it overlaps alternately the ends of the slide valve in a greater or less degree, according to the amount of the expansion. The valve rod is attached to the expansion slide frame in the usual manner, and made hollow, in order that the rod of the ordinary slide valve may pass through it, or it may be made also solid, similar to that of the slide valve, and worked through a separate stuffing box either above or at one side of the slide rod. The fixed pivot or short weigh bar supports the two levers that are worked or fixed upon the said pivot or short weigh bar, as the case may be; the lower end of one of the levers is connected by the links and the rod to the expansion slide frame, and the upper end of the other lever is connected by the rod to the back eccentric, or for working the engine backwards, so that by the gearing thus described the said eccentric communicates its motion to the expansion slide frame. There is a groove or slot in which the pin at the end of the rod moves; and also gearing by which the engine driver can vary the position of this pin at pleasure, and thereby cause the stroke of the expansion slide frame to correspond exactly with the amount of expansion required. A dial is placed at the foot plate in view of the engine driver, which indicates minutely the amount of the expansion at any part of the stroke. When expansion is not required, the pin is raised into the loop, and at the same

time the inclined surfaces on the end of the lever p
which keep the expansion slide frame firmly secure
out of gear, and thereby prevent all unnecessary we

This arrangement was the first of its kind to cut
separate valve with the use of the main valve.

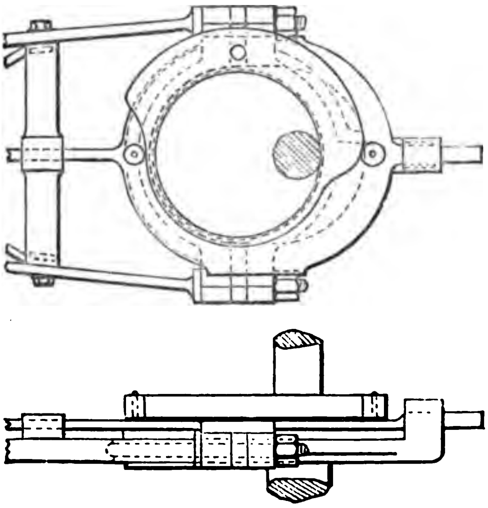
In the year 1844, Mr. James Petrie, of Lancast
the ranks of inventors, with his idea of what a
should be, which was an arrangement of a cutti
placed in the inside of the main valve, and both bei
and an eccentric. The form of the valves and ca
the cylinder is shown by Fig. 23, in side and front

Fig. 23.



These two bars are finished to a plane surface on both sides, viz., on the side which slides on the facing on the cylinder nozzle, and also on the side enclosed by the semicircular part of the main valve ; on the last-mentioned surface is the sliding plate or "cutting-off" valve for cutting off the steam, and both valves are connected together by means of rods passing through stuffing boxes in the bottom of the top steam box, and in the top of the bottom box; these two sliding plates are connected with gear hereafter described in such a manner as to cause them to partake of the motion of or move along with the main valves for any portion of the stroke, and also to move on the inside facing of the main valves, so as to close either of the openings, and thereby cut off the steam for the remainder of the stroke. When the sliding plate covers the port in the face of the lower main valve, the top sliding plate is in such a position to leave the port in that valve uncovered and *vice versâ*. The cam and eccentric gear is shown in side elevation and plan by Fig. 24. The eccentric is made broader on the periphery or edge than usual, and has a groove turned in it, as in common, for the reception of the clips connected to the common eccentric rod. This groove is close to one edge; and on the remaining portion of the breadth is fitted a moveable cam. The edge of this cam is concentric with the eccentric, except at the two inclined portions. These inclined portions act on friction rollers that are connected to an elliptical ring, to which is attached a rod which leads to the "cut-off" valves. This elliptical ring is steadied by guides so as to move only in a direct line with

Fig. 24.



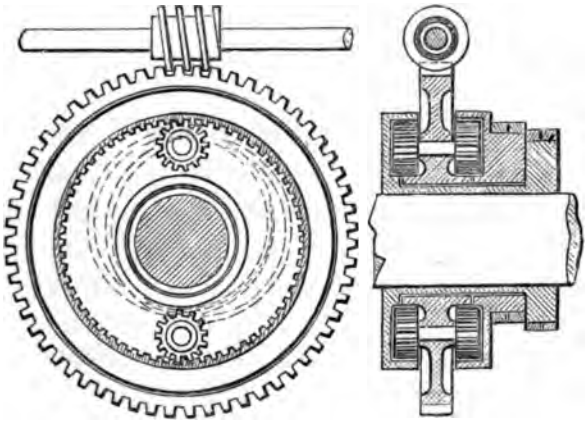
Petrie's combined Cam and Eccentric Valve Gear, for two Slide-Valves for Land Engines, patented in the year 1844.

the respective rod to which it is attached. The point at which the steam is cut off is varied by shifting the movable cam, on the common eccentric, either forwards or backwards as required. As the cam revolves along with the eccentric, and as the acting surface of the cam is, as stated before, concentric with the eccentric, except at the projections, this motion will alternately draw the cam rod backwards and push it forwards. Mr. Petrie, also, at the same time, proposed an arrangement of gearing in connection with the engine-governor, which was a very complicated combination of bevel and mitre wheels, worm and wheel, cams, and sun and planet motions, with levers and weigh shafts, eccentric rods, and the necessary details attending the whole.

After Mr. Petrie, Mr. Leigh of the same county, came, in the year 1849, with his appeal for a patent, which was granted for his invention of valve-gearing as particularly applicable to oscillating engines for marine purposes, which class of engine had just then came into consideration: we may mention also that Mr. Leigh trod pretty hard on Mr. Petrie's toes in this matter as far as the worm and wheel, and sun and planet motions were concerned; although Mr. Petrie shows his application as for stationary engines.

Mr. Leigh's valve-gear is shown in side and end elevations by Fig. 25, and the arrangement of the detail is as follows:—Upon the crank shaft is keyed or otherwise firmly attached an eccentric for the purpose of effecting the ordinary motion of the slide valves, surrounding its toothed wheel and pinions turn round the other pinions, which will communicate motion through the spur wheel to the loose eccentric, at an uniform speed and in the same direction with that of the fast eccentric, providing that the worm wheel shall remain stationary; in which case the eccentrics will actuate the slide valves and expansion valve uniformly at every stroke of the engine. But if the said worm wheel shall be caused partially to revolve, then, by means of the pinion, the loose eccentric will be caused to move around the crank shaft, and its position relatively with that of the fast eccentric will be altered; and in order to effect this, a worm wheel is connected with the governor of the engine by means of a worm mounted on a shaft, the other extremity of the said shaft being provided with a roller running upon a friction disc.

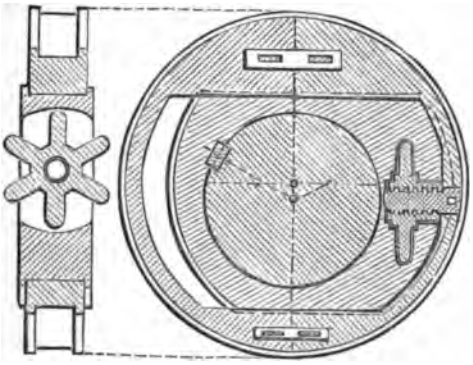
FIG. 25.



Leigh's combined Tooth-wheel and Eccentric-Gear, for two Slide Valves for Oscillating Marine Engines, patented in the year 1849.

In the year 1850, Mr. Charles Atherton, of Devonport, patented a series of mechanical arrangements for adjusting the "throw" of the eccentric by a regulating screw and nuts, and also by gearing, and other nearly similar contrivances diversely situated: the pith of his entire proposals is embodied in the arrangement illustrated by Fig. 26 in two sectional views; which is that the body part of the eccentric is so formed as to enclose or contain a block which surrounds the crank shaft and is fixed at an angle thereon. The eccentric proper has fixed in its body a regulating screw, that passes through a hand-nut, and on turning the hand-nut, the eccentric can be shifted in either direction as required. We have added the eccentric in halves and the connecting pins and keys to Mr. Atherton's imperfect drawing accompanying his specification so as to make it practically understood here; it may be noticed, also, that the hand-nut may be turned around while the eccentric is in motion by means of a ratchet, which can be shifted by a handle, and screwed rod attached thereto for that purpose.

Fig. 26.



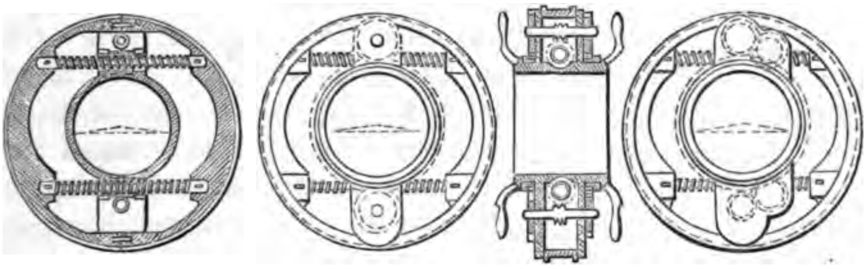
Atherton's Adjustable Eccentric for attaining a range of cut-offs with one Valve, patented in the year 1850.

Mr. Atherton proposed nine different methods of valve-gearing in all, eight of which were far more complicated than that illustrated here by Fig. 26, they being a complication of—screws passing end to end against the shaft, screws one each side

Fig. 27.

through the shaft, but in such position that the axis or centre line of the screw is not only parallel to the centre line but also passes through the axis of the shaft, and a nut, of which the circumference forms a bevelled pinion wheel, is attached to the shaft like a swivel, which on being turned round operates upon the screw. The four illustrations, Fig. 28, represent three other arrangements of eccentric apparatus in which the regulating screw does not pass through the shaft, as in Fig. 27: but two regulating screws are made to pass one at each side of the shaft, and each of these screws is fitted with a nut, the circumference of which is formed to form an endless screw wheel or rack work, which is operated upon and turned round by the tangent screws. And as these nuts are confined between the snugs or ears which project from the shaft or from the ring that is fitted to the shaft, while the snugs are so situated on the shaft that the centre line or axis of the leading screws shall be parallel to the centre line of the eccentric; it follows, then, that the regulating screws will be so fitted that the centre of the eccentric wheel may be made to move in either direction on that centre line according to the direction in which the tangent screws are turned.

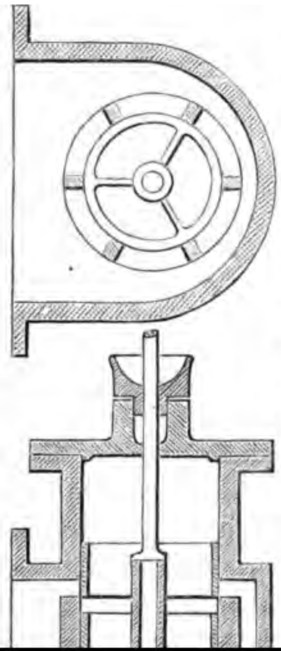
Fig. 28.



Atherton's Adjustable Eccentrics for attaining a range of cut-offs with one Valve, patented in the year 1850.

Now, in order that the tangent screws may be turned in either direction, each end of the spindle of each tangent screw is fitted with a pinion wheel, and one side of the eccentric wheel is fitted with a spur wheel, as shown in the second view, running loose upon the saddle concentric with the centre of the shaft, and in gear with the pinion. But when the other side of the eccentric, as shown by the third view, is fitted with a spur wheel running loose on the saddle, but communicating with the pinion by means of the intermediate wheel by which the pinion and wheel are always in gear—all of which parts are also shown by the section—then by such an arrangement the tangent screws can be turned in either direction, according as the wheels on the one side or on the other may be held; or the toothed wheels, may be grooved pulleys, connected by bands so arranged as to produce the same result; and for the purpose of stopping the wheels or pulleys, stop handles, as in Fig. 27, page 30, may be attached to the wheels or stop levers, so as to obstruct their motion; or the stop levers may if required be so constructed as to be connected with the engine governor in such manner that the self-acting operation of the governor upon the expansive gear may regulate the speed of the engine.

FIG. 29.



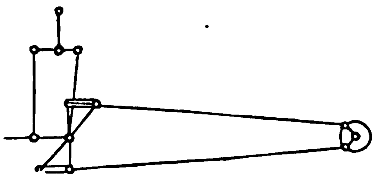
The most efficient portion of Mr. Atherton's patented ideas is his expansion valve which is perfectly equilibrium, and since the year 1850 has likewise formed, of such dimensions and distances apart as to correspond with the apertures in the expansion valve representing the faces between the apertures. The steam has constant and free access to the interior of the expansion slide; and it is obvious that if the valve apertures are opposite to the casing apertures the steam will pass and get access to the main valve; but if the faces of the expansion valve are opposite the casing apertures, then the valve faces will also cover those apertures, and the steam will not pass, but be what is termed cut-off.

In constructing this expansion valve with a view to its being worked by the eccentric motion just before described, and produce the effect of cutting off the steam at any required period of the stroke for which the said eccentric may have been adapted, it is requisite that the length of the respective faces, or spaces between the apertures, be not less than the radius of the largest circle which the centre of the eccentric wheel or centre of the crank pin of the crank motion can be made to describe.

Nothing particular was done in valve-gearing worthy of record from 1850 until 1855, when Mr. Alexander Allan of Perth invented and patented his now well-known "Straight Link-Motion." It may be well to state that link-motions at that period were divided into two classes, termed the "stationary link" and the "shifting link." The stationary link motion was also divided into two kinds, namely, those in which the block was connected to the valve connecting rod through which its motion is conveyed to the valve, and those in which the eccentric rods were connected to the block. In the former case the link was curved to the radius of the length of the valve connecting rod, and the concave side of the link was placed towards the valve, and in the latter case the link was curved to the radius of the length of the eccentric rods, and the concave side of the link was placed towards the eccentrics. With the shifting link-motion the eccentric rods are usually connected to the link which is worked on the block, the link being curved to the radius of the length of the eccentric rods, with the concave side placed towards the eccentrics.

Mr. Allan's link-motion was a new combination of this mechanism, the novelty of which is, that the peculiar features of both the shifting and stationary link arrangements were combined, as both the link and block—or parts corresponding thereto—are moved to get the block pin or centre at the required position in or on its link or centre. As a consequent of such an arrangement, a link may be made with a varying or unlimited radius or combination of radii, or the centres of the double lever; parallel motion may be employed by attaching radius rods to a central bar, which carries the valve radius rod centre, as shown by the diagram Fig. 30. The other ends of the radius rods are connected to the eccentric rods, which are kept at the required distance apart by a strap or plate or straps and plates. He however preferred to employ a straight link, as shown by Fig. 31, in plan and elevations, which may be a box, open, or a bar link, according to convenience, as it will be found that the curves or arcs described by the movement of the eccentric and valve connecting rods will neutralize or compensate each other, and thus effect the object of the usual curve of the link in common motions. The movements of the link and block, or parts common thereto, were accomplished simultaneously, by jointing the rod, corresponding to that by which the link is sustained or suspended in the stationary

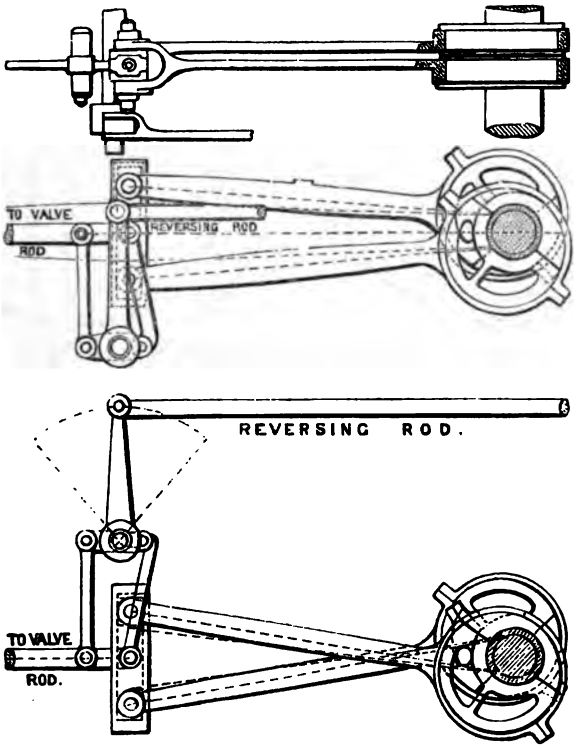
FIG. 30.



Allan's diagram of his Straight-Link-Motion. Patented in the year 1855.

in construction, and more easily maintained in repair than common link-motions; it requires less room than the shifting link; the angular position of the eccentric rods as compared with the one class, and the valve-connecting rod as compared with the other class of common link-motions, is much reduced; consequently the eccentric and valve rods move through less space and are more direct acting; the eccentric rods, link and valve-connecting rod and block, or parts belonging to them, balance each other, or nearly so, and thus dispense with a counterbalance weight; and, lastly, less power is required to move to or fix the valve gear in the required positions than in the common link-motions.

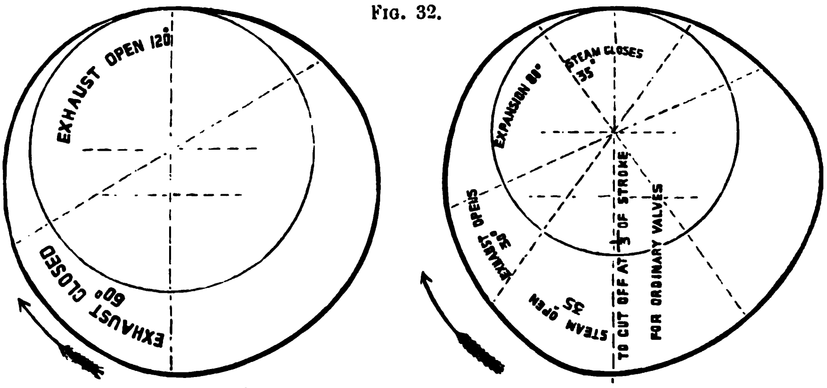
FIG. 31.



Allan's Straight-Link-Motion, patented in the year 1855.

In the same year, 1855, Mr. Kenworthy, of Lancaster, introduced a differential eccentric for working the slide valves of steam engines. He shaped the curves or form of the driving edges of the eccentric on mathematical principles, as shown by Fig. 32. Mr. Kenworthy arranges his method for shaping the curves as follows: Suppose it is required to construct a differential eccentric to cut off steam at five-twelfths of the stroke of the piston with a common slide valve. First fix upon the size of the boss to suit the diameter of the crank shaft, then set the crank pin so that its radius will give the eccentricity required to traverse the valves. Now, five-twelfths of the stroke corresponds nearly to an angle of eighty degrees, that is to say, the steam must be shut off when the

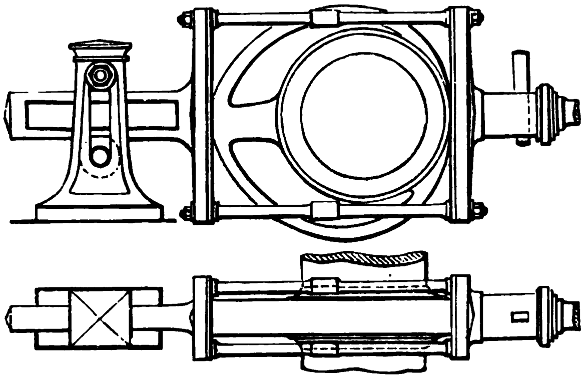
Fig. 32.



Kenworthy's Differential Eccentric, patented in the year 1855.

then say, close steam opening one inch and a half, equal to forty degrees, expand by lap two inches, equal to seventy degrees, exhaust opens two inches, equal to thirty degrees, open for steam one inch and a half, equal to forty degrees, total seven inches and one hundred and eighty degrees. The construction or setting out will be thus:—First make the radius or small crank on the drawing paper equal to three inches and a half, so that half a revolution will give a traverse of seven inches; then set off on a disc upon which the eccentric is to be delineated or drawn the respective angles, or from the ring of the disc, which shows the number of degrees, and then join those points by the curves as illustrated. The Fig. 33 is a side elevation and plan of the eccentric and frame as arranged for direct action; and Fig. 34 is an elevation of another of a different form.

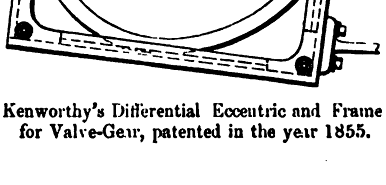
Fig. 33.



Kenworthy's Differential Eccentric and Frame for Valve-Gear, patented in the year 1855.

It will be remembered that on page 28 we noticed that Mr. Petrie, in the year 1844, proposed a complicated arrangement of valve-gear, and we now illustrate an improvement on that gear, which was

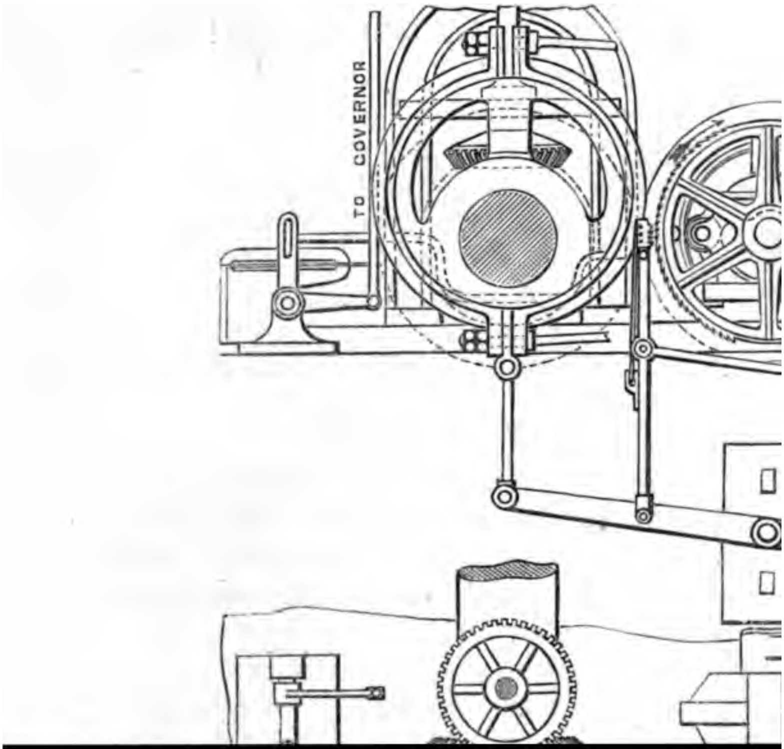
Fig. 34.



Kenworthy's Differential Eccentric and Frame for Valve-Gear, patented in the year 1855.

patented in 1856, by Fig. 35, which is a differential
ing the slide valves. The gear is partially enclosed i

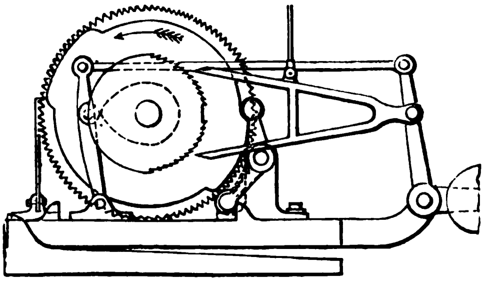
FIG. 35.



revolves on the shaft, receives motion from the crank shaft by means of the spur wheel keyed thereon, and gears into the wheel fixed upon the boss of the wheel. Upon one end of the shaft the ratchet wheel is also keyed, and which is actuated at suitable periods by the swinging catch levers, which are attached by suitable joints and pins to the vibrating lever mounted upon the stud, secured in a suitable manner to the framework of the engine. The lever receives motion in this instance from the eccentric by means of the connecting rod or link attached thereto, so that a vibratory motion will be imparted to the actuating clicks attached to the catch levers or arms. To the lever or arm is also connected a rod, the other end of which is by a suitable joint connected to the bell-crank lever, keyed on the shaft or stud mounted on the bracket. The other arm of the bell-crank lever has a rod or bar connected at its upper end to the lever, which partakes of the variations of the governor. Suppose that the speed of the engine is required to be reduced, the governor would, by means of the lever, rod and bell crank, actuate the swinging lever and click, so as to cause it to operate against the ratchet wheel, thereby causing the said ratchet wheel to turn in the direction as indicated by the arrow, at the same time by means of the retaining wheel and variable wheel altering the relative position of the cam, which effects the "cutting off" with the valves. Should the speed of the engine require to be increased, then the action of the swinging catches would turn the ratchet wheel, and consequently the cam, in a reverse or contrary direction, thus regulating the expansion and speed of the engine. To prevent any undue fluctuation of the governor, there is a spring or other suitable elastic medium attached to the brackets or frame at one end; the other end thereof acts against a lever fixed upon the spindle or bar. The force of the spring may be increased or diminished by moving the part in the slot. The motion of the cam may be imparted to the valves or slides by any other suitable arrangement of apparatus; that, however, preferred, is shown with a friction roller or bowl, against which the cam acts, and is mounted in a frame which slides in suitably formed grooves or slots, and to

which the rod or bar is attached that connects it
that regulates the steam in the engine cylinder.

FIG. 36.



Petrie's arrangement of the Cam, Catches, Levers, and Rods of his Expansion-Gear, patented in the year 1856.

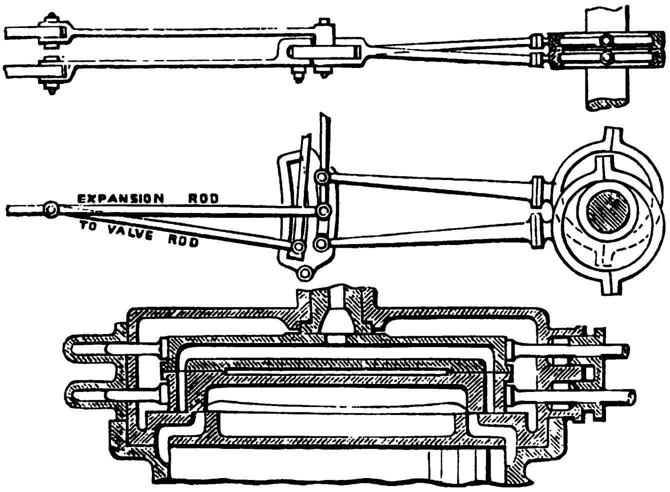
Fig. 36 is a skeleton view of the details that es
stopping or
the gear. T
is shown, as
closed. The
the interme
wheel, upon
usual bevel
municate m
wheel, are sh
38. Upon
the wheel th
the boss of which has also the heart wheel fast
cam, which communicates motion to the valves
off the steam, in the manner before mentioned. Th
loose on the shaft to which the ratchet wheel is a
swinging catch lever, mounted on the lever or
centre in a bracket or other suitable part formed
shown in position out of gear. The rod or bar con
catch to the governor is vertical. Instead of
retaining wheel being locked, as before described,

those on the periphery of the wheel, which will thus partly hook or hold it; or an arrangement of friction apparatus may be employed for this purpose if most applicable.

From the foregoing description it will be evident that as the governor actuates the double swinging lever, the heart wheel and ratchet wheel will effect the desired object of changing the relative position of the cutting-off cam, and consequently alter the position of the slides or valves with respect to the steam ports or passages. The differential wheels are actuated by the wheel which gears into that on the crank shaft, as before explained.

In the same year, 1856, Messrs. Charlton and Turnbull, of Essex and Surrey, patented a peculiar arrangement of link-motion and double valves in connection therewith. The illustrations shown by Fig. 37 are

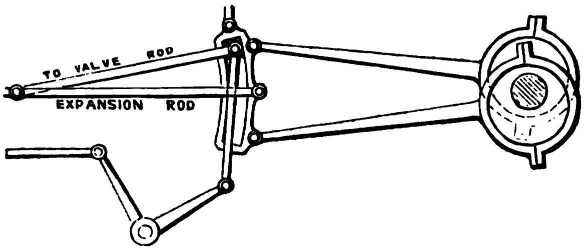
FIG. 37.



Charlton's Double-Slotted Link Motion, with Single-ported Main and Expansion Slide Valves, patented in the year 1856.

a side elevation and plan of the link-motion, and a section of the slide valves and casing, with a portion of the cylinder. The eccentrics are keyed on the crank shaft in the usual manner, and are encircled by the eccentric bands, which are firmly secured to the eccentric rods, the ends of which are forked and jointed to the double slotted link by pins. The eccentrics are fixed on the crank shaft, to correspond to a backward or forward motion of the engine. The link is suspended by a rod jointed to it by a pin; the other end of the rod is jointed to the bracket below in a similar manner. The bracket is permanently fixed to any suitable part of the framing or foundation plate, or to any suitable part of the boiler or engine. This rod keeps the link in proper position, but at the same time it is capable of vibrating while being actuated by the eccentrics through their straps and connecting rods. In the slot of the link a block is fitted; the sides of the link and block are flush, or nearly so. The connecting rod has both ends forked—in the same plane,—one end of which spans the link and embraces the block, and is jointed to it by a pin, which is passed through them. The other forked end of the rod is jointed also by a pin to the valve spindle, for the purpose of giving motion to the slide valve, which has ports—one at each end—which are formed right through from front to back. The valve ports correspond with ports in the cylinder face, the steam ways of which lead to their respective ends of the cylinder. The cylinder ports are nearer to each other than those in the valve, to allow space for the stroke. The expansion valve is formed hollow, and has two ports in its face to correspond exactly with the ports or passages in the main valve; a space is formed between the face of the expansion and gear and rods can be omitted. The link is suspended at the top in this case, instead of at the lower end, as in Fig. 37.

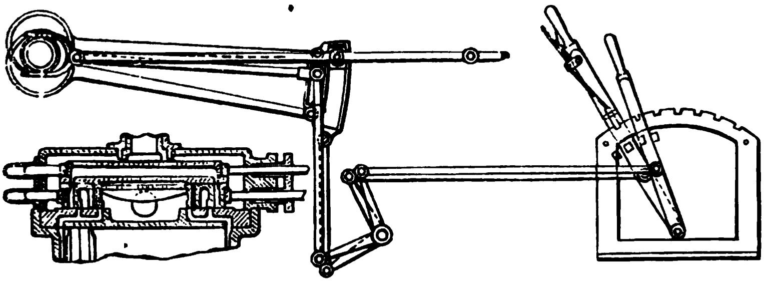
FIG. 38.



Charlton's Link-Motion for working the Main and Expansion Slide Valves, patented in the year 1856.

The next illustration, Fig. 39, is an arrangement of the double slotted link, which is *shifted* by rods and levers that are fixed by means of pins and catch plates—those previously described being fixed links—

FIG. 39.



Charlton's Shifting Double-Slotted Link-Motion, with Double-ported Main and Expansion Slide Valves, patented in the year 1856.

but the mode of shifting the slide blocks in the slots of the links is as in Figs. 37 and 38. In this arrangement the link is shifted on the block to fit it for a forward or backward motion; while to work or set the parts to work the expansion valve the block is shifted in the slot, and kept in any desired position by a small catch or projection, formed on the handle, let into notches formed in a segmental catch plate attached to the reversing handle, which is held by the catch plate. A rod jointed to the block by a pin, leads in a direction toward the crank shaft, which it spans or partially surrounds. Near the forked end of the rod another rod is jointed, which works the valve by being connected to the valve spindle.

Below the eccentric rods is a longitudinal section of another modification of the valves applied thereto; the main valve has *two* steam ports in each end through it; the cylinder has a corresponding number of ports, two of which open into the steam ways or passages to each end of the cylinder; the expansion valve, having a similar number in its face, which is fitted on the back of the steam valve.

About this date, 1856, the idea of improving or simplifying the link-motion was vigorously exerted, and the principle of Williams's link eccentric-band, as illustrated by Fig. 20 on page 22, was again revived, and that too by an important member of the now well-known firm of Sharp, Stewart, & Co., of Manchester. Mr. Stewart, and his friend Mr. Hope, of the same place, patented, in 1857, their "improvements in valve gear for stationary and locomotive engines."

They obviated the use of the *curved* or Stephenson link by the adoption of a *straight* link, either slotted or solid, as best suitable for certain positions of the valve gear; and the principles of their mechanical arrangements are, that they proposed to hang or support the straight link in the same manner as the ordinary stationary reversing link, and in connecting the sliding block, by a rod or link, with the end of the described by the end of the arm of the reversing shaft, but of the latter motion it only receives a diminished proportion, causing the joint of the valve connecting rod to move in a curve practically equivalent to that which would be required in the ordinary curved stationary link.

The curve required is obtained by adjusting the length of the arm from the reversing shaft, and the distance of the joint of the valve connecting rod from the point on the sliding block. When the valve connecting rod is jointed to the link connecting the sliding block and arm from the reversing shaft at a point between the joint of the sliding block and arm of the reversing shaft, the curve described by the end of the valve connecting rod will have its concave side towards the reversing shaft; but if the point of attachment of the valve connecting rod is on the opposite side of the joint of the sliding block, the curve made by the end of the valve connecting rod will have its convex side towards the reversing shaft.

It will be obvious, from what has been stated, that the rod connecting the sliding block and arm of the reversing shaft becomes a lever, through which the movements of the link are transmitted, which movements will be consequently increased or diminished, according as the valve connecting rod is attached to it on one or the other side of the joint on the block; that is, according as the lever is made one of the second or third kind. This will necessarily have to be taken into consideration in the proportion of the ports and throw of the eccentric or eccentrics. The eccentric or eccentrics are set, and the link is suspended or sustained, so that when the sliding block is in the middle position upon its link, the valve connecting rod will be perpendicular to the link.

Next as to regulating, reversing, and transmitting the motion for working the valves. The general mode to accomplish that consists in a lever having two or three arms combined with a crank, or radius pin, or an eccentric, one arm of the lever being connected with the crank, radius pin, or eccentric, the fulcrum of the lever being so arranged that it can give way to the rectilinear motion imparted to it, the eccentric, crank, or radius pin being also arranged in a certain position relative to the crank or piston of the engine; and the combination and arrangement of mechanism just referred to will produce a motion to work the valve of a steam engine so as to rotate its crank in either direction, and will also give motion to a valve having lap, that is, one which extends over the steam ports when in the central position, so as to work the steam at various grades of expansion.

As a crank or radius pin and an eccentric are mechanical equivalents, and as eccentrics only are shown in the relative illustrations, further on, for working the lever, the word eccentric will hereafter only be used. We may add, however, that the lever is constituted by the clip of the eccentric and a reversing link or part of one combined together, the eccentric clip forming one arm of the lever, and the link or part of the link the other one or two arms thereof.

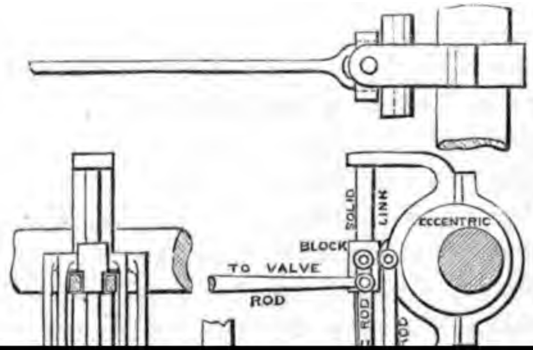
The eccentric is placed on the crank shaft of the engine, or on a shaft connected with the engine, driven by it uniformly with the crank shaft. The position of the eccentric in relation to the crank or piston of the engine is obtained as follows:—Set the engine with the piston at one end of its stroke, place the valve connecting rod or slide block in the central position of its link, in a line with the fulcrum of the link and centre of the shaft upon which the eccentric is placed. In this position, if the eccentric is rotated, the valve will receive a certain amount of traverse; and the correct position of the eccentric is that in which the valve will have nearly arrived at one extremity of the traverse, when the central position, and the space of the steam port to be uncovered at the commencement of the stroke—when the motion is taken directly from the slide block of the link to the valve, so that it will receive the same amount of motion as the sliding block. But if the motion of the sliding block is not given directly to the valve, but is transmitted through levers which increase or diminish it, then the preceding rule as to the radius of the eccentric will not apply: the eccentric in such cases must be of such throw as will, when acting through the levers employed, place the valve in the proper position at the end of the stroke of the piston, this being tested by the motion taken from the middle position of the link, in the manner described for setting the eccentric.

The proportions of the lengths of the arms of the lever, or clip and link combined, are about equal, but when the throw of the eccentric is fixed upon, or the lap and lead of the valve is fixed upon, and an increase of motion in the valve is required, it is obtained by making the arms of the lever, represented by the link, longer than that arm of the lever represented by the eccentric clip. It will be obvious that the lever or link has a compound motion, derived from the direct and angular motion given by the eccentric, that part of the link at the fulcrum partaking solely of the direct motion, the angular motion increasing as the distance increases from the fulcrum, and it will be found on examination that the angular motion in one direction is a little less than that in the other direction, and would consequently give a little more admission of steam on one than on the other side of the piston; but this is compensated by means similar to those employed to attain this object in ordinary link-motions, that is, by causing the block to slide on or in the link as it moves backwards and forwards, so that the block will go further from the fulcrum of the link as it travels from that side, which, but for this compensation, would have most admission to that side which would have the least admission, which is accomplished by arranging the position of the reversing shaft, so that the fulcrum of the rod to which the valve connecting rod is attached is on one side of the centre line of the reciprocating motion imparted to the valve connecting rod, namely, on the opposite side to that which is to receive the extra or compensating movement.

In engines which do not require reversing, but only a variable travel of the valve, and where the position of the block in the link is regulated by a screw, the admission of steam to the cylinder on both sides may be equalized by placing the fulcrum of the radius bar sustaining the fulcrum of the link on one side of the centre line of its oscillations, namely, on that side opposite to that on which the extra movement is required.

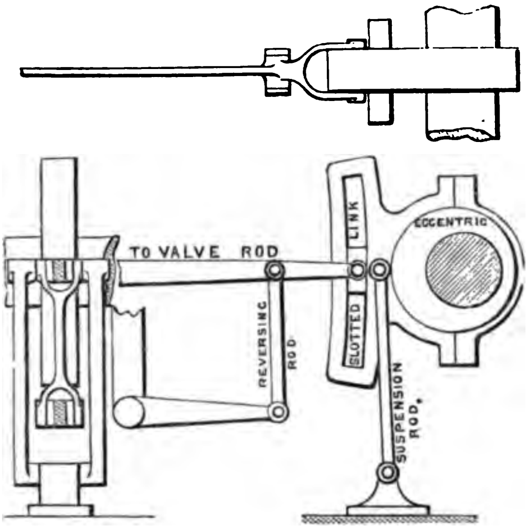
Thus far the principles of this valve gear are explained, and we next illustrate and describe the mechanical arrangements that fulfil them. Fig. 40 shows a side and end elevation, also a plan of the

FIG. 40.



all shown in position and connection. Fig. 41 is an arrangement with a *curved* slotted-link, also applicable for stationary engines.

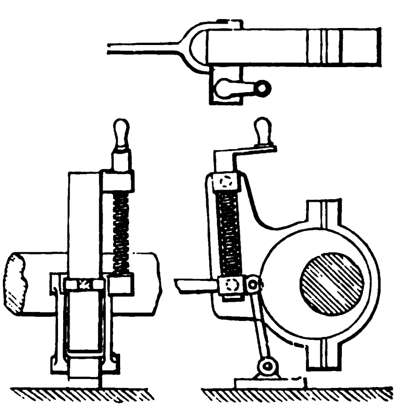
FIG. 41.



Stewart's Curved Slotted-Link-Eccentric, Reversing Valve-Gear for Stationary Engines, patented in the year 1857.

Fig. 42 illustrates an arrangement of slotted-link eccentric for non-reversing valve-gear, half part of a link only being required. In this case a screw is arranged as shown, having a handle, by which the slide block can be moved in the link, to vary the travel of the valve as required. The fulcrum of the radius bar in this and in the other modifications before described, is supposed to be held on a bracket secured to the bed plate framing, or some part of the foundation of the engine.

FIG. 42.



Stewart's Straight Slotted-Link, Eccentric Valve-Gear for altering the travel of the Valve for Non-reversing Stationary Engines, patented in the year 1857.

In applying this valve-gear for

reversing, to locomotive engines, certain arrangements are necessary to keep the fulcrum of the link in the same relative position with the crank axle, as any change of this position would affect the movements of the valve or link.

In the ordinary link-motion the link is sustained from the framing of the engine; but as the action of the eccentric rods is only in a horizontal direction, the vertical movements of the carriage or frame of the engine up and down, or to and from the axle, do not sensibly affect the motion of the link or valve, the length of the eccentric rods being great in comparison with the extent of the vertical movement of the carriage to and from the axle.

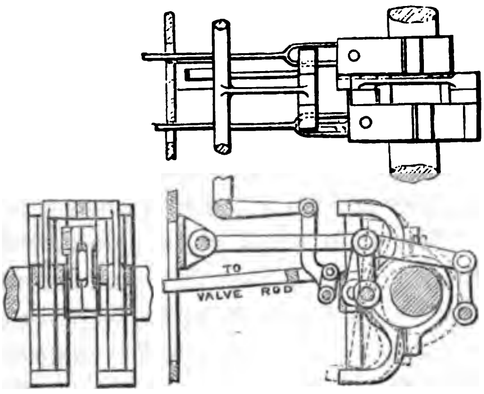
One method of overcoming the irregularities caused by the varying position of the axle in relation to the framing, is to fix the eccentrics on a separate shaft placed on a level with the crank shaft, and support it in bearings attached to the framing; this shaft being rotated at the same speed as the crank shaft by toothed wheels or by other arrangements.

Another method is to make the crank shaft an intermediate shaft, or one not having any wheels attached, the power of the engine being conveyed to the driving wheels by coupling rods or other means.

A third arrangement is, by supporting the fulcrum of the sustaining link on a bracket resting upon or embracing the crank shaft, the bracket being prevented from turning or moving out of the position fixed upon, by guides attached to the framing, which allow it to give way only to valve-gear outside, where the eccentrics are near together: and consists in arrangements whereby the clip of one eccentric is made to impart motion to a lever, so as to agree in time, direction, and extent, as near as required, with the movements of a part from the clip of the other eccentric, these two parts being connected together by a rod jointed to each, so that the forces acting upon the clip of one eccentric are counteracted by the forces acting upon the other; the centre of the lever being comparatively motionless under the action of the two eccentrics, and only requiring to be connected to the framing of the engine by a rod placed in a horizontal position, so as to prevent the links rotating with the eccentrics and to allow of the movements of the carriage of the engine.

In this arrangement the eccentrics and links are arranged as before described; a centre is adopted, upon which both radius rods for sustaining the fulcrum of the links oscillate. These radius rods are in length equal to the distance of the fulcrum of the link from the centre of the eccentric; one of them has an arm extending from it at a right angle, this arm being double the length of the radius rods; and to its end one end of another rod is jointed, of the same length as those sustaining the fulcrum of the links; the other end of this connecting rod is jointed to the back clip of the other eccentric, the joint on the eccentric clip being in a line drawn from the fulcrum of its link through the centre of the eccentric, and at a distance from the centre of the eccentric equal to the length of the radius rods. That centre upon which the radius rods oscillate, which sustains the fulcrum of the links, is the one which is comparatively motionless, and is the one attached by a connecting rod to the framing.

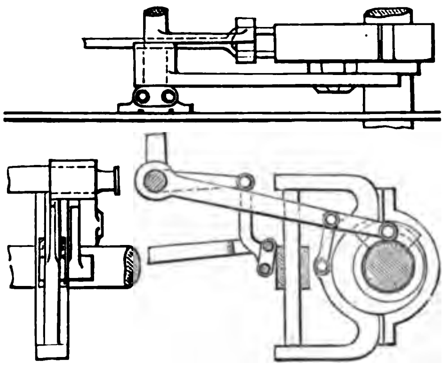
FIG. 43.



Stewart's Straight Solid-Link-Eccentric, Reversing Valve-Gear, for Locomotive Engines with inside Cylinders, patented in the year 1857.

The illustrations shown by Fig. 43, on the preceding page, are side and end elevations, with a plan of solid-link-eccentrics as applied to locomotive engines with inside cylinders. This arrangement is, that the radius rods sustain the fulcrum of the link, and the centre on which the sustaining rods oscillate, is the rod connecting this point with the framing of the engine. There is an arm extending at a right angle from the sustaining rod of one eccentric, thus forming a lever or rod connecting the end of the arm with the back of the clip of the other eccentric. The slide block of the link, and the joint pin upon it, the reversing shaft, the arm or arms from it, the rod or rods connecting the arm of the reversing shaft and the sliding block, and the valve connecting rod, are all shown also.

Fig. 44.

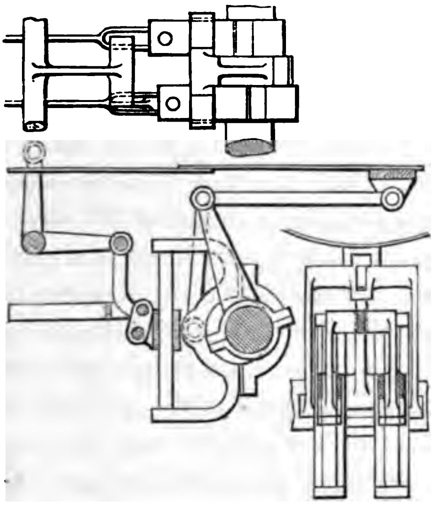


Stewart's Straight Solid-Link-Eccentric, Reversing Valve-Gear, for Locomotive Engines with outside Cylinders, patented in the year 1857.

Fig. 44 shows the valve-gear applied to engines having their cylinders on the outside of the framing. In this case an arm is centered on the reversing shaft; the end of this arm is jointed to the segmental piece that fits and enters a circular groove formed in the side of the eccentric, and the sustaining rod is connected to this arm.

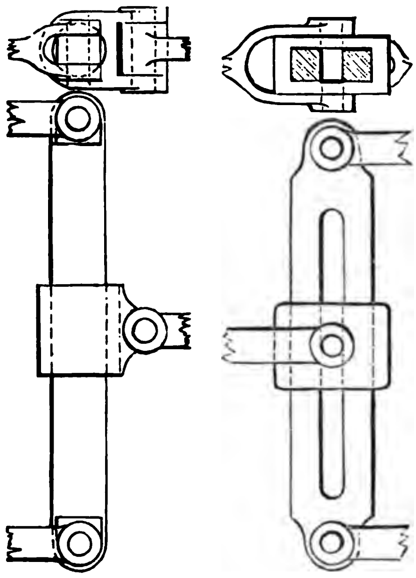
section, and the sliding block has a hole of corresponding form, a slot being made in the link equal to the length of the traverse of the sliding block for the pin, which forms the centre upon which the valve connecting rod, or the rod connected to the reversing shaft arm is jointed; the pin passing through both link and sliding block. These links, when used in connection with two eccentrics, are suspended in the same manner as ordinary stationary link motions, that is, either from one end or from the centre, in which case a piece is added to one or both sides, with a pin for the connecting rod.

FIG. 45.



Stewart's Straight Solid-Link-Eccentric, Reversing Valve-Gear, for Locomotive Engines with inside Cylinders, patented in the year 1857.

FIG. 46. FIG. 47.

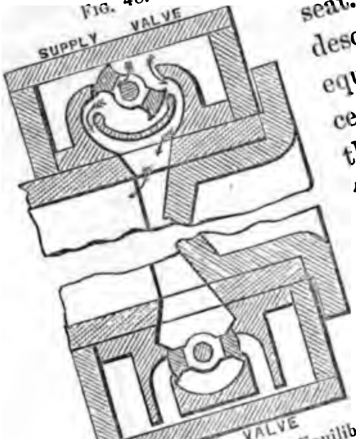


Stewart's Straight Solid and Slotted Links and Blocks, patented in the year 1857.

Valve-gearing had a rest from the last date mentioned until 1860, when Mr. Newton, of London, received a communication from New York, America, to patent in England for Messrs. Crosby, Savage, and Stearns, the valves and gear now to be described. These supply and exhaust valves—showed opened and closed—are illustrated by Fig. 48,

are each composed of two eccentric segments, which may be unit
ne end or at both ends, and are provided with a journal at one
at both ends, to work in a suitable bearing or bearings in the side or ends of the valve box, or in the side or of the steam chest, which contains the seat. The faces of the two segmen described from two different centres, w equidistant from, but on opposite side centre of oscillation of the valve. The through the valve extends nearly fro to the other between the two ec ments. The valve thus constructe its sides parallel with its axis, or tapering form. The seat for this faces, which correspond in shape of the valve, so that the valve tight therein, and in each sea

Fig. 48.

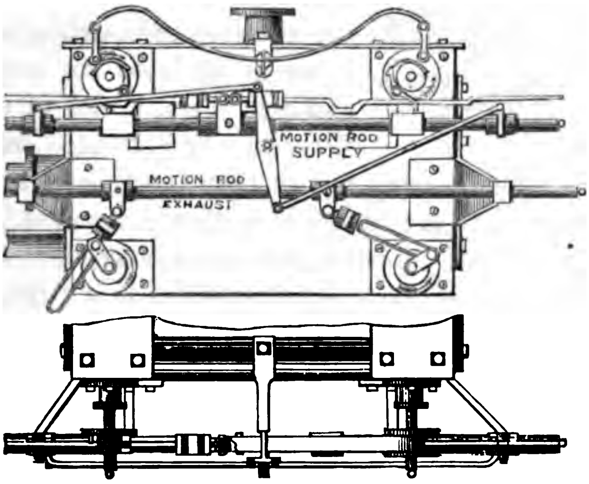


Crosby's Oscillating Equilibrium Segmental cut-off and exhaust Steam-engine Valves, patented in the year 1860.

It was proposed, generally to a box, which can be inserted chest or other place where the valve is to be used, removed therefrom with facility. In applying thes engine, a set of four is necessary, viz., two for s exhaustion; the supply valves being arranged o exhaust valves on the opposite side of the cylind contain the supply valves have a some in connection with their port the exhaust valves. ports, a seats, and it is only while the valve is closed that it touches the seats, and hence it works without any friction but that of its journal or journals, which is inconsiderable, and without any wear of its faces. It may be mentioned, also, that the pressure of the steam on the excess of surface presented by the sides of the segments of the valve will tend to keep the valve closed tightly. This excess of surface is, however, so slight, that the pressure upon it causes comparatively little resistance to the opening of the valve.

The gear for working these four valves is illustrated by Fig. 49, in elevation and plan. The cut-off gear is over that for the exhaust valves, and both consist of an arrangement of levers, rods, and shafts, in connection with cranks or levers on the main crank shaft, which latter are shown by Fig. 50 on the next page. The following is a description of the whole of the details and their relation to each other :—The cylinder of the engine is furnished with a square casing. The steam pipe on the top admits steam to both of the two steam chests, on which are the stems

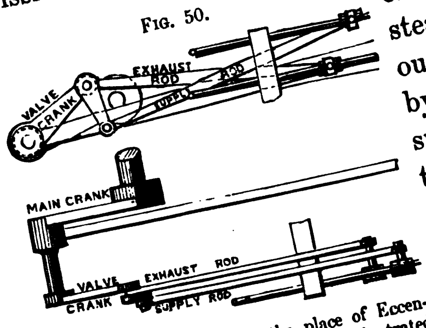
FIG. 49.



Crosby's Valve-Gear for the Oscillating Valves shown by Fig. 48, patented in the year 1860.

or rods of two oscillating supply valves, fitted to ports in the chests at opposite ends of the cylinder; one of the valves effe mission and cut-off of the steam at one end, and the other a end of the cylinder. Each o or rods has secured to it, o steam chest, a plate having outer face, and these plates by links with opposite end spring, which is held by a to the cylinder, so applied constant tendency to tur the direction indicated b it, so as to close its and each valve, if not tion as to be prevente

Fig. 50.



Crosby's Crank Motion in the place of Eccentrics for working the Valve-gear illustrated by Fig. 49, patented in the year 1860.

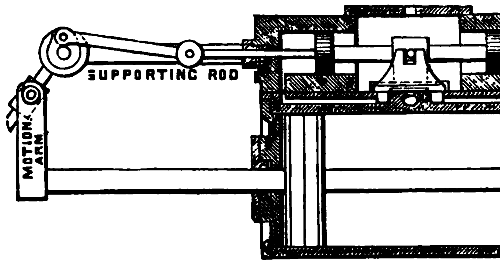
the direction in which it closes further than is necessa have a stop applied, to prevent such further movem plates has attached to it, outside of its boss, a lever-l capable of swinging freely on the pin by which it is of these dogs has applied to it a spring which is at its respective plate, and which acts upon it in such the upper end of it towards the boss, and throu therefrom. These dogs are applied on the sides o plates, which are opposite each other, and are arra that when pressure is applied to the toes of the force the other ends of the dogs into contact wit plates in the opposite direction to that i to open the valve.

connecting-rod, the lever being so arranged relatively to the main crank pin as to give the rod the lead for the valve, to cause it to commence its stroke in either direction before the commencement of the stroke of the piston in that direction. A block is firmly secured to the motion rod, and having attached to it by two pins above the rod, one end of each of two similar bars, each of which bars is supported at some distance from its other end on one of two rollers, each of which rollers is fitted to one of two blocks. These blocks are fitted to slide upon the rod, and are connected by two rods, one for each, with opposite arms of a lever, which is arranged to work on a stationary fulcrum, for the purpose of adjusting the position of the blocks. The two bars which are used may be termed catch bars, are free to work vertically, or in a plane parallel with the face of the plates on the pins, and are straight, with the exception that each has a recess in its upper side, and has, some distance further from its pin, a step on its under side. These bars move along with the motion rod, and in such movement work between the plates and upright guide pins, which are secured in the guides.

It is obvious, from the two illustrations that have been just illustrated and described, that complication in relation to valve-gear must have been deemed a superlative accomplishment by the inventors; for they evidently strained all means possible to make complication—instead of simplicity—perfect in their arrangement; so much so indeed, that nothing, it would appear, could be added to what was proposed, either for assistance or improvement. They forgot, however,—*i. e.* if they knew—that the more simple the arrangement of any kind of mechanical contrivance is, the more perfect its action will be; or similarly, as in describing anything, the better the person who explains it is informed, the fewer words he will use to make himself fully understood.

In the beginning of the year 1862, a Mr. Steele applied for, and did get, a patent granted for his idea of what the most simple valve-gear should be. His arrangement is illustrated by Fig. 51, which is a longitudinal sectional elevation of the entire apparatus. In the illustration is shown the engine cylinder enclosing the piston and rod, also the valve casing, having attached to it at opposite enc cylinders situated in a line with each other, and pa cylinder. These cylinders are open to the valve c

FIG. 51.



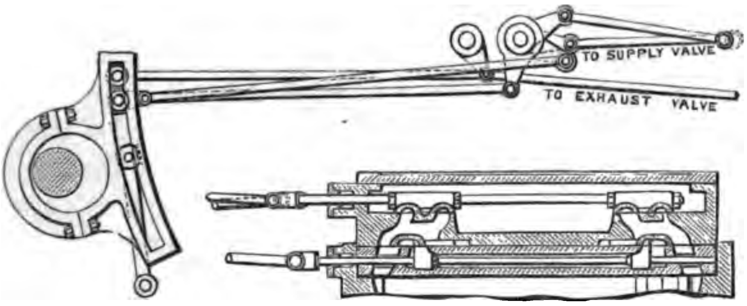
Steele's Steam Self-acting Valve-Gear, patented in the yea

ends, but closed at their outer ends, excepting th stuffing box for the passage of the valve rod.

The main valve is of the kind known as the valve, with its seat having the usual arrangeme ports and exhaust port. At the side of the val parallel or in the same plane with it, is the sea valve, which is like the main valve, only narrower arrangement of ports that are narrower, as they passage of a very much smaller quantity of steam. municate by the passages to the outer ends of the c diameter, to allow for a considerable degree of the lost motion of the rod with respect to the valve; the object of which is, that while both valves are operated by the same rod, the secondary valve may always have the lead of the main valve. The valve rod is connected outside of the cylinder by a connecting rod with a short crank, which is loose on a fixed stud secured in a rigid arm, attached to the main cylinder, or in any other fixed support. This crank serves to limit the movement of the valves, and also to effect the first part of the movement thereof in either direction. The stud has also fitted loosely to it a lever, on which there is formed a fork, embracing the crank, but made so much wider as to permit the crank to make a quarter of a revolution of the crank within the said fork. The lever is fitted into a joint-piece, that is pivoted by a pin to an arm that is rigidly secured to the main piston rod.

Our next description is that of the "Allen" valve-gear, patented in 1862 in England, the inventor being a mechanic of New York, America.

FIG. 52.

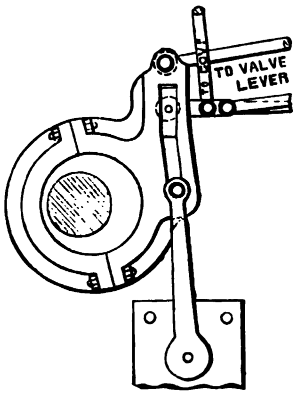


Allen's Reversing Link-Eccentric Valve-Gear and Double Valves, patented in the year 1862.

The illustration, Fig. 52, represents a side elevation of this valve-gearing for a steam engine in which the separate movements of the supply and exhaust valves are derived from a "link" operated by the revolution of a single eccentric operating those valves independently of each other, and capable of adjusting the points of cut-off of the supply valves as well as of reversing the motion of the engine.

To effect this, a slotted rocking lever or "link" is used, which is pivoted centrally by the fulcrum pin to the upper end of a sustaining rod that is hinged at its lower end to a fixed pin. This lever or link is attached to or forms part of the strap of the eccentric, which eccentric is secured to the main shaft of the engine. The link is slotted nearly through from end to end. In this slot are held two sliding blocks which can pass each other. The upper block is connected through the rod with an arm on a rock shaft, on which another arm is attached, connected through the rod with the exhaust valves. This block is fixed at a point in the link from which in connection with the arm or other gearing it will give to the said exhaust valves the correct motion. The lower block is connected to a rod, to which, a short distance from the link, another rod is attached. These two rods are attached to separate arms, secured to separate and independent rock-shafts, of which one passes through the other, so as to have a common centre of motion. On the end of the shaft to which the main vertical arm is fastened a lesser arm is attached, communicating through the connecting rod the motion to the supply valves on one end of the cylinder, and on the end of the shaft to which the lower arm is fastened, an arm above the other is attached, communicating through the connecting rod, motion to the supply valves on the other end of the cylinder. The positions of the arms working above and below the line running through the centre of the rock shaft and the slide valve rods are similar, position at the other by the amount of the eccentric's throw. The eccentric is so set relatively to the engine crank that these said points will coincide or nearly coincide with the commencement of each stroke of the piston ; and the laps of the valves are made such, that at one end of the said points the steam valve is about commencing to admit steam to the back end of the cylinder, while when required at the other end, it is about commencing to admit steam to the front end of the cylinder. The portion of the piston's stroke during which the steam valves will remain open, will increase in proportion as the lower block occupies parts of the link more remote from the fulcrum pin. The movement of the valve derived from the lower half of the link will cause the engine to run in an opposite direction from that derived from its upper half. The lower block from which the supply valves derive their movements being separated from and working independent from the upper block, from which the exhaust valves derive their movements; any position of that block,—and consequently the extent to which "expansion" may be advantageously caused—will not interfere with the correct action of the exhaust valve, as would be the case if the motion of the steam and exhaust valves were taken from one and the same block or point in the slotted lever or link.

Fig. 53.

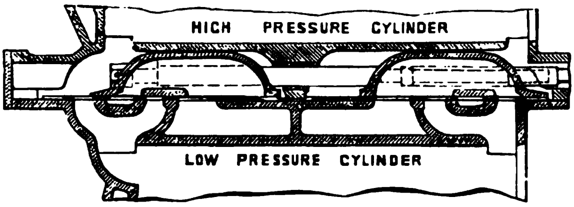


Allen's Non-reversing Link-Eccentric Valve-Gear, patented in the year 1862.

Fig. 53 represents a side elevation of an eccentric and connections for a non-reversing engine having a governor for regulating the speed. In this description of engine it is not desired to have the motion of the engine reversible, in consequence of which the upper or lower half of the link—as the case may require—can be dispensed with, and the link be made only with a single slot, in which the block that operates the steam valves is movable. The exhaust valves derive their motion in that case from a pin fixed in the solid part of the link. The governor rod is connected with the block, whereby the different degrees of expansion according to the load on the engine will be regulated.

The next example that is worthy of record as an improvement in valves and gearing is Mr. Elder's, of Glasgow. His valves are shown by Fig. 54, which is for combined high and low pressure cylinders, acting

Fig. 54.

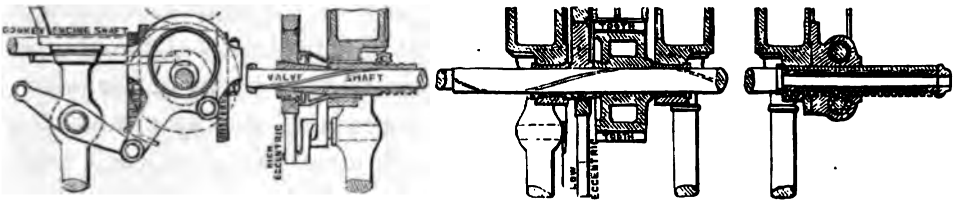


Elder's Multiple-ported Slide Valves for combined Cylinders of compound high and low pressure Steam-Engines, patented in the year 1862.

as an intermediate-valve between them, the view being a longitudinal section showing the arrangement of the valves and cylinder. The steam, in passing from the high-pressure cylinder to the low-pressure cylinder, leaves the former by ports opening into two intermediate valve chambers. The valves are fixed upon the same rod, which passes from one chamber to the other through a gland, and they work upon port faces, each having an exhaust port and two inlet ports communicating with the low-pressure cylinder. One valve is shown as having uncovered one being shaped so that the former as it were fill up those ends of the latter towards which they move in cutting off the steam.

Besides that, Mr. Elder patented at the same time an arrangement of valve-gear—of which Fig. 55 is a sectional elevation and an end view —as arranged for engines for driving paddle-wheels. The valve shaft is driven by means of a toothed wheel connected to it by a straight groove and feather, so as to admit of the shaft's movement endways, and this wheel is in gear with an intermediate wheel over it, which last is driven by means of a wheel fast on the main shaft, not shown. The valve shaft wheel, and the eccentric at the side for working the low-pressure valves, are mounted on the same shaft, between bearings which keep them from being moved endways when the shaft is so moved, and the eccentric is connected to the shaft by a spiral groove and feather, in consequence of which the endway movement of the shaft alters the position of the eccentric relatively to the wheel, and therefore to the crank shaft. For the purpose of moving the valve shaft endways, there is fitted on it at the right-hand end between collars, a loose tubular piece formed with rack teeth, with which there gears a pinion on a shaft driven by a small donkey engine. This arrangement of valve-gearing relates also particularly to the mounting of the "high" eccentric at the left hand, which works the valves of the high-pressure cylinders. Such eccentric has hitherto been connected directly to the valve shaft by a spiral groove and feather, as in the case of the other eccentric; but by this modification it is mounted upon an elongated tubular boss, shown in section also. This tubular boss is fitted upon the valve shaft with a

FIG. 55.



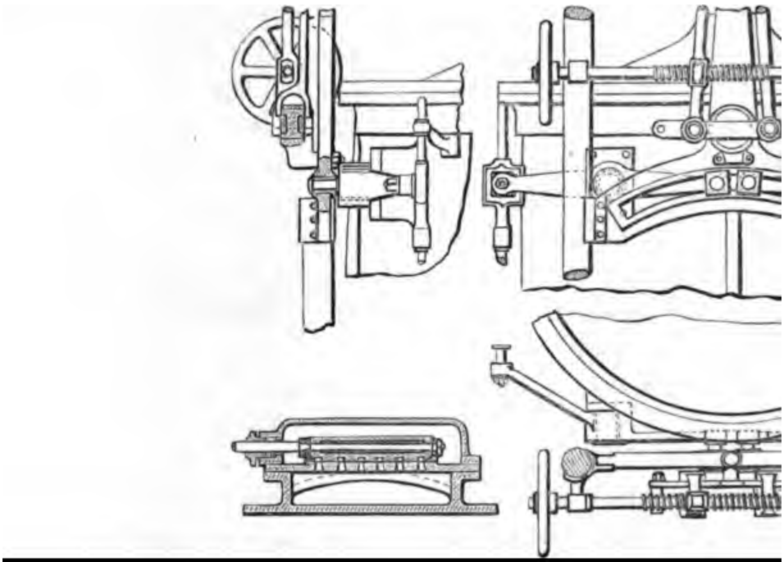
Elder's Expansion-Gear for Oscillating Paddle-wheel Engines, patented in the year 1862.

spiral groove and feather, so that its position in the circle relatively to the main cranks may be altered by the endway movement of the valve shaft simultaneously with that of the " low " eccentric. The tubular boss is formed externally with a cylindrical surface disposed obliquely to the valve shaft, and the high eccentric is bored with corresponding obliquity to fit on such oblique part, whilst its proper rectangular position is retained relatively to the shaft. The axis of the oblique piece is in the line passing through the axis of the shaft and through the centre or axis of that eccentric, so that an adjustment of the oblique piece through the eccentric varies the eccentricity or throw of the latter. This endway adjustment of the tubular piece is effected by means of a pinion, the teeth of which gear with teeth upon the piece, such teeth being cut round the piece to admit of the latter revolving without getting out of gear. The pinion is fixed on a shaft, which may be actuated by a hand wheel or other convenient means to effect the adjustment when it is wished to vary the throw of the eccentric, and consequently the period of cut-off. To keep the eccentric in its place, it is formed with a collar, which is embraced by grooved sleeves formed upon the brasses of the bearing in which the parallel portion of the tubular boss turns, and which supports that end of the valve shaft.

Directly after Mr. Elder had carried out his ideas as to the arrangement of perfect valve-gear, for oscillating engines in particular, Mr. Caird stepped forward with his invention, which was also [redacted] the link. This arrangement of the valves forms a good balance, and it enables the expansion to perhaps be carried out in a much more effective manner than can be accomplished acccording to the usual plan. To a segmentally slotted bar or cross-head piece, similar to that ordinarily employed for the communication of the eccentric's motion to the main slide valves, without any derangement from the oscillatory action of the cylinder, there is attached at the centre a cranked stud. This stud is bolted in laterally, and is cranked upwards, terminating in a large eye. This eye is bored out horizontally to embrace a traversing bush cylindrical in external form, but recessed laterally on each side, or formed with top and bottom shoulders to fit into the expansion lever link. This link is composed of two plain bars or curved segmental pieces bolted together, with a space between them for the traverse of the bush therein. It is from this stud as a centre that the motion of the eccentric is conveyed to the valve. One end of the link is joined in the usual manner by a fixed stud to the lower end of the eccentric rod from the main shaft, and the link thus receives the vibratory action necessary for the operation of the valve. The opposite end of the link is similarly jointed to the lower end of a *pendent* radius rod or bar, the upper end of which is fitted with a ring to embrace a concentric collar or shoulder on the main shaft, or fixed to a stud placed as near the centre of the shaft as possible: thus this rod has no longitudinal traverse motion, and its lower end forms the fixed supporting centre for the link to work upon. This lower end is fitted with an adjusting screw, spindle, lever, and link movement, or other adjusting arrangement, so that it can be set in or out from the main vertical centre line of the cylinder, and thus vary the effective throw of the link, and consequently alter the expansive action of the valve. This system of valve-gear is applicable to all classes of steam engines and valvular apparatus, and it is available as well for the main slide valves as for separate expansion valves. The adjustable radius bar always keeps the centres correct, and forms a steady fulcrum for the link motion, whilst its adjustment is so simple that the engines can be handled with great facility.

This arrangement, excepting the eccentrics, is
side and end elevations, also in plan. The ste
together with the supply and exhaust passages t
are each arranged in the manner common to engi
each side of the trunnion through which the s
arranged the expansion valve, shown in section
which regulates the admission of the steam t

FIG. 56.

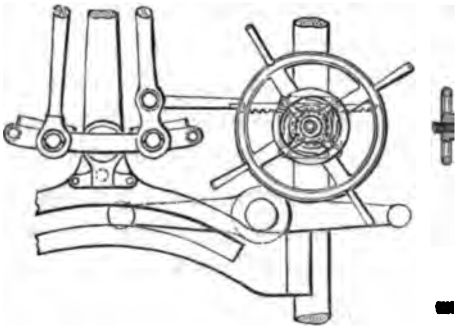


central part, in which a bush is fitted, to admit of its being connected by means of a bolt and nut to the ends of the bent levers. These levers are each centred on a stud, the back plate of which is secured to a projecting part cast on the face of the cylinder. The inner arm of each of these levers extends towards each other, and terminates in a brass bush or block, so as to traverse easily to and fro in the segmental slot, which is formed in the bar or cross head. The cross head is formed with a prolongation that extends in an upward direction, the extremity passing through the eye of a guide, which is bolted to the beam of the framing, the lateral extremities of the cross head being bolted to guide brasses which partly encircle the columns of the framing. To the centre of the cross head is fixed a cranked stud, which is cranked in an upward direction, and terminates in a large eye. In this eye is fitted the traversing bush, which is recessed in a lateral direction on the front and back, or formed with top and bottom projections which embrace the expansion lever link, as shown in the end view in section. This link is composed of two plain bars or curved segmental pieces, which are bolted together at the extremities, leaving a space between them for the traverse of the bush. One end of the link is jointed to the lower end of the eccentric rod, the reciprocatory movement of which is communicated to the expansion valves. The other end of the link is joined in a similar manner to the *pendent* rod, the upper end of which is bolted to a strap that encircles a ring on the main shaft. Instead of this arrangement, the rod may be fixed to a stud arranged as near the centre or axial line of the main shaft as possible. A slot is formed in the lower part of the rod, in which is fitted a nut, and through this the horizontal screw works. This screw is supported in bearings, which project out from the columns of the framing, and on one extremity is fitted the hand wheel. By turning the hand wheel the screw is put in motion, which causes the rod to move in a lateral direction either to the right or left, according to the direction given to the hand wheel by the engineer. In this way the link is caused to move in either direction, so that it can be set to or from the vertical centre line of the cylinder,

and thus vary the throw of the link, and so alte
of the valves to the extent that may be found des

Another mode of arranging the mechanical
these expansion valves is shown by Fig. 57, in si
elevations. In this arrangement the lever with t

FIG. 57.



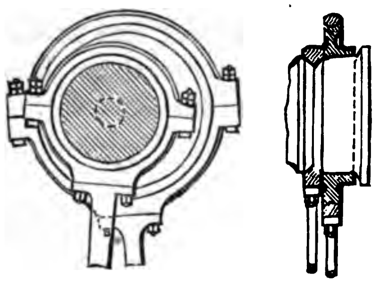
Caird's Link-Motion and Reversing Gear, patented in th

stud, and link, are similar to the corresponding p
The lower ends of the eccentric rod and the *pend*
fitted with brasses, which form the bearings for
rod is jointed by a link to the horizontal rack,
pinion on the back of the hand wheel. This w
stud which is bolted to the column of the fram
this stud is formed with a shoulder to receive

are fixed in the position desired by screwing up the hand wheel: which wedges the boss of the wheel, and holds the parts securely. In this way the expansive action of the valves may be regulated and adjusted with the utmost ease and facility.

The illustration, Fig. 58, is a side and sectional end elevation of the eccentric and concentric-ring, with their bands for working the motion last described, and illustrated by Figs. 56 and 57.

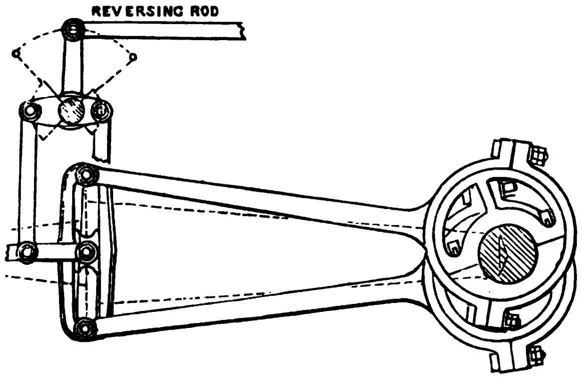
Fig. 58.



Caird's Eccentric and Ring for working and suspending the Link, patented in the year 1862.

Link-motion at this date had reached an advanced stage of perfection. As for example, Allan had improved his straight link considerably, as shown by Fig. 59, which contrasts widely with that illustrated by Fig. 31 on page 35.

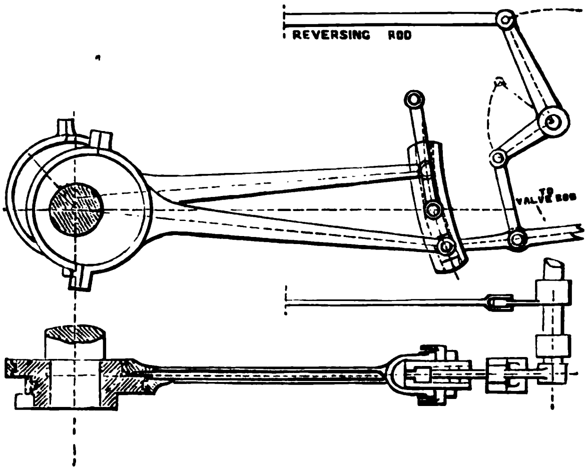
Fig. 59.



Allan's Improved Straight Link-Motion, exhibited in the International Exhibition in the year 1862.

Mr. Gooch also, now Sir Daniel, the well-known railway engineer, had modified his previous adoption of Stephenson's link by the arrangement shown by Fig. 60. The eccentrics are keyed on the shaft as usual, and actuate the rods in connection with the link, the convex side of which is turned from the shaft, instead of towards it, as with the "lifting" or Stephenson link. The Gooch link is formed of two bars very similar, as the original "Allan link" was, and is hung at the centre by a swing or radius bar on each side, so that the travel of the centre of the link, due to the motion of the eccentric, is always on the arc described by those bars. The block between the link bars is connected to the slide valve rod by a rod which is raised and lowered by levers and rods termed the reversing-gear, so that in this case the

FIG. 60.

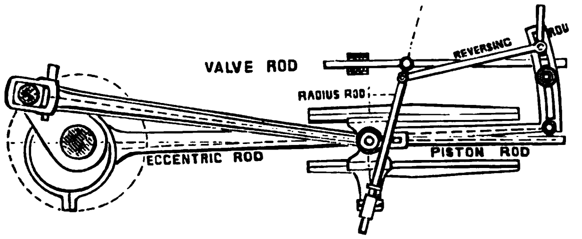


Gooch's Suspended Box-Link-Motion and Reversing Gear, patented in the year 1862.

The eccentric rod imparts to the link an oscillating motion, that terminates at the fixed pin supporting the link. The link has a curved slot, in which the sliding block, which is connected to the radius rod, can be moved up and down, by means of the lifting rod, in order to produce a variable expansion of the steam as required.

The radius, or reversing, rod is connected at its end to two levers, which at their upper ends are fastened by joints to the valve rods, whilst their lower ends move in sliding and vibrating bearings, formed with the piston rod's cross heads. Each lever has thus a very peculiar motion given to it; the one end moves with the piston rod backwards and forwards, while the other joint end receives from the link another oscillating motion, and the valve-rod joint is thus brought into such a motion as is suitable for working the valve, as experience has shown where practically carried out.

FIG. 61



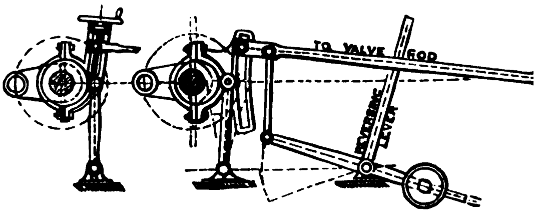
Heusinger von Waldegg's Single Eccentric, Fixed-Link-Motion, and Reversing Gear, as arranged in the year 1862.

A very simple fixed link-eccentric motion has been proposed by Pius Fink, also a German engineer, as shown in Zeuner's work, dating there from the year 1857, as illustrated by Fig. 62 on the next page. This is the single eccentric link-motion, the link being formed in the half-band of the eccentric and supported by a rod. A lever which swings from the fixed point is coupled to this link at the joint, so that the joint moves backwards and forwards almost on the centre line of the stroke, whilst simultaneously with the turning of the shaft, oscillating movements of the link take place from this point.

The radius rod, which is connected with the valve rod, is moved up and down in the link by means of the bell-crank is connected by the lifting rod. The engine runs t one or in the other direction, according to whether th placed below or above the dead point of the link; the shifting of the block governs the grade of expansio

This valve-gear has especially been used for st which have to work with variable expansion, but whic run in the same direction. For such cases only the on is constructed as shown in elevation at the left hand, block is then fixed at any required point of the linl screw and handle. The difference, *viz.*, whether the

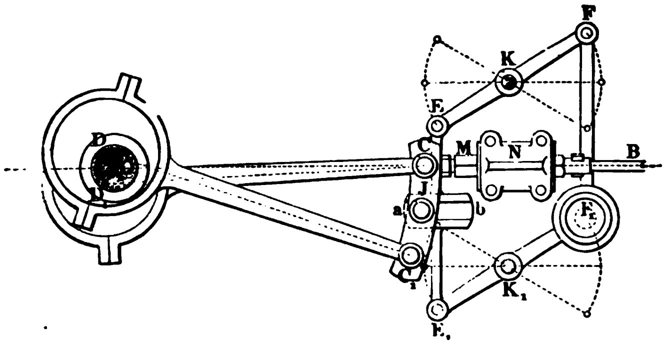
FIG. 62.



Pius Fink's Link Eccentric Motion and Reversing Gear.

radius rod is effected through a bell-crank by means o rod, or whether the block is fixed in the link by a scre into consideration during any theoretical investigation ment of the valve will be different in the two cases, block moves up and down in the link during its working arms EF and E_1 F_1 in a direction parallel to each other, and the guide *a b*, which is fastened to the vertical rod EE_1 and is provided with a slot parallel to the centre line O B, will thus always occupy positions at which this parallelism remains unaltered. In the slot of the guide *a b* the centre pin J of the link moves backwards and forwards. The parallelogram, which is provided at F_1 with a counterweight, can be moved from the footplate on which the driver stands, in the same manner; the shafts marked with KK_1 are for both levers identical in application. MB represents the valve-rod and N its guide, the link appears as lowered: and as the eccentrics are arranged, the engine, when the different parts are similar, as shown in the figure for a locomotive, will run forwards.

FIG. 63.

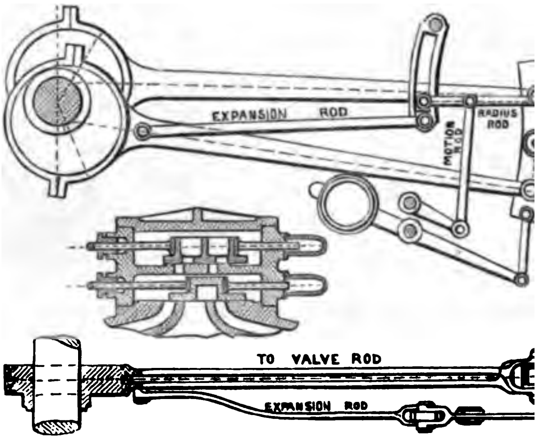


Von Landsee's Link-Motion, with parallel suspension bars.

Besides the arrangement of link-motion by English engineers, that we have already illustrated, for working *two* slide-valves, one over, or on, the other—the under valve being for exhaustion and the upper for supply and expansion—the German engineers have proposed and adopted various methods, three examples of which we select from Zeuner's work. The first we refer to is by Gozenbach, as represented by Fig. 64 on the next page, in side elevation and plan, with the section of the valves between the two views. The links are the box and slotted kinds, and perform separate duties. The box link is in connection with the main or

exhaust valve, which valve is only used for effecting e
or backward motion of the engine, or for bringing it
this is produced by either fully lowering the link by m
and the rod in connection, so that the forward eccen
the valve-rod, or by fully raising the link, so that th
its motion from the backward eccentric, or finally, by
in its central position, so that the dead point of the lin

Fig. 64.



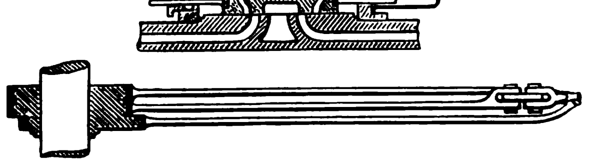
Gozenbach's Separate Link-Motions with only two Eccentrics fo
working the double Valves with a Divisional Seating.

the valve-rod, and consequently, on account of the c
of the steam which takes place at this position of the
engine to a standstill.

But the other positions of the link are not e above it, and thus receives an oscillating motion. The end of the radius rod moves up and down in this link, and may be fixed in a certain position by means of the lever and the motion rod; the radius rod is connected at its end with the rod of the expansion valve, so that the backward and forward motion of the block is transferred to the latter. Of course the nearer the block is to the fixed portion of the link, the less is the stroke of the valve. The main valve is a common valve, the outside and inside lap of which, however, is taken in the present case smaller than usual; but the expansion valve, which moves in a separate steam chest upon the cover of the steam chest of the exhaust valve, is a *gridiron valve*. If the slots of that valve coincide with the openings in the seating between the two steam chests, the steam enters into the chest of the main valve; and the expansion will begin as soon as the expansion valve shuts those openings. The slots in the expansion valve are generally a little larger than the openings in the seating.

The next German example we notice is by Meyer, and has *three* eccentrics, as shown, by plan and elevation with a section of the valves,

Fig. 65.



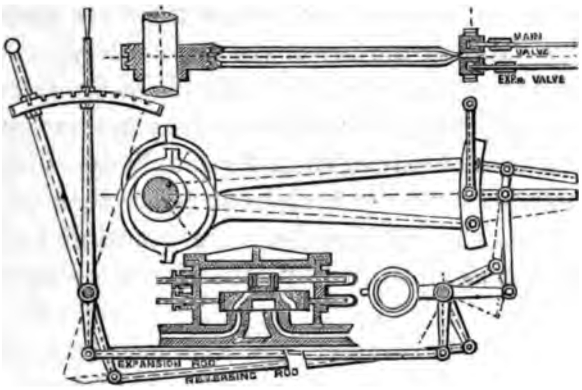
Meyer's Treble Eccentric Gear with Link-Motion for working the double Valves.

by Fig. 65. The arrangement of the gear is as follows:—The main valve is moved by means of a link on Stephenson's system, and the only utility of the link in the present instance is for the purpose of reversing or stopping the engine, which is produced by the use of the central point or the dead point of the link to govern the valve. This valve consists of a plate through which are two ports, and between them are the bars and the port for the release of the steam. These two outer ports move backwards and forwards over the ports of the cylinder, and allow the steam to enter into the cylinder through the latter ports, it being supposed that the expansion valve does not cover the corresponding port on the top. The expansion valve consists of *two* plates, which virtually form two screw-plates with right and left-hand threads, and are thus connected with the valve rod, which of course is also formed for a corresponding length with threads of the same kind. Thus if the valve rod is turned around, the two plates will, according to the direction of the turning, either approach each other or be moved farther apart. The expansion valve is therefore a kind of twin-plate, which may either be lengthened or shortened, by which means, as the figure on the preceding page illustrates, an earlier or later cutting-off of the steam occurs, and thus a variable expansion will be produced.

The turning of the valve rod for the variation of the expansion may be effected during the running of the engine by the following arrangement. The end of the valve rod has for a certain length a square section, and on this portion is placed a small pinion, this pinion not being fastened to the rod, but being kept in its place by some other means. The rod moves, during the motion of the engine, an eccentric rod; the eccentric is fastened on the shaft, in this case, at an angle of advance of nearly 90°."

The third example that we have referred to is by Polonceau, and consists of twin links, but single eccentrics to each link, as illustrated by Fig. 66 in side elevation and plan, also a section of the valves and cylinder ports. The links are the box kind: their convex sides being turned towards the crank shaft, and are suspended by bars or rods that are fixed on a stationary centre or pin, and thus they receive an oscillating motion from the two eccentrics fixed on the crank shaft. The arrangement of these parts is therefore somewhat the same as used by Gooch. The sliding block for the main valve is by the radius rod moved in one link; similarly as illustrated by Fig. 60 on page 70; this radius-rod is connected with the valve-rod of the main valve, so that the latter receives its motion from the swing joint of that link.

FIG. 66.



Polonceau's Twin Single Eccentric Link-Motions and double Valves.

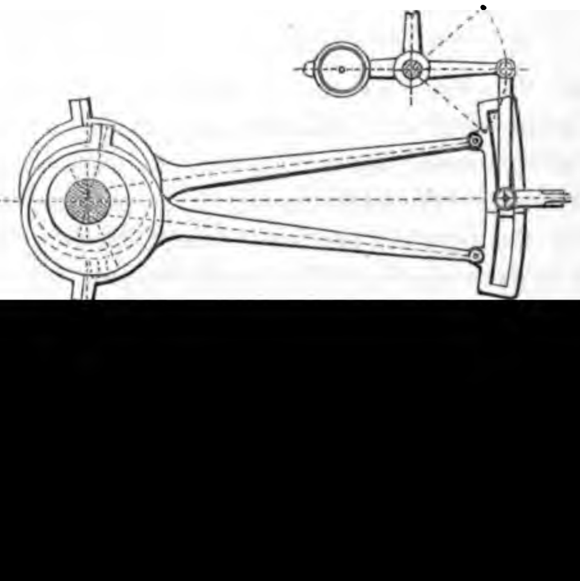
The sliding block, for the expansion valve, is by the other radius-rod moved in the other link; and this radius-rod therefore transfers the motion of the joint of this link to the expansion valve.

The movement of the two sliding blocks by means of the lowering or raising of the radius rods is effected by the driver by means of the reversing levers, the ends of which are connected by rods with the bell-crank levers, whilst the rods transfer the movement to the radius-rods, and thus the valves are shifted.

The reversing levers move in the quadrant guide, which is provided with notches, and in which the levers can be fixed at different positions, in the usual manner, by means of springs. The main valve is nearly of the same shape as that in Meyer's valve-motion, shown on page 75. The expansion valve, however, consists of a simple plate enclosed in a frame, but moves also on the top of the main valve.

Those six last examples portray the aptitude of the German engineers for modifications of link-motion; but while we pay them our compliments for ingenuity, we cannot extend them for simplicity, as in all cases complication has been particularly carried out rather than avoided. As for example, as a contrast, what can be more beautifully simple than our English link-motion as illustrated by Fig. 67. Here we have simplicity

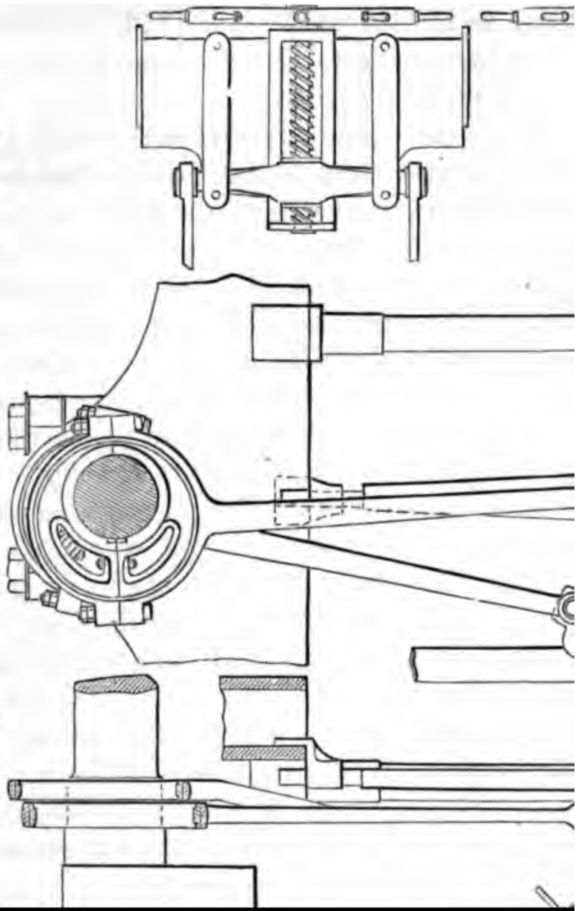
FIG. 67.



in England by Englishmen as far back as the year 1843. In mentioning this we may add our purpose is to place the laurels where they belong, without prejudice or national feeling.

We must notice next the marine-engine link-motion as arranged to the year 1862 : treating first of the gear for oscillating paddle-wheel engines, and we may remark that the arrangement of the detail requisite to impart the motion to the slide-valve forms an important consideration with the marine-engine, and more particularly so when the oscillating type is dealt with. The cylinder vibrates, and also its appendages, and the main accomplishment is a vertical motion for the slide-valves, independently of their lateral motion. To produce this a sliding quadrant is requisite, and the efficiency of this detail depends on the curve of the slot. The correct shape of this curve is undoubtedly *semi-elliptical*, the lesser radius being at the extremities. For practical purposes, an uniform curve is usual, the radius of which is—the angular distance between the centres of the sliding-blocks and the trunnion, when the working levers are on the horizontal line. The illustration, Fig 68 on the next page, is an arrangement of " link-motion and starting gear " of a pair of oscillating engines constructed by Messrs. James Watt and Co. The eccentrics are in halves, connected by bolts; the rods being of the ordinary kind, with double eyes to clasp the link. The peripheries of the eccentrics are fitted with brass hoops with projections to suit the recesses formed in the bands of the rods, the hoops being also recessed on the eccentrics to prevent lateral movement. The link is the usual shape, with brasses in the eyes, adjustment being caused by cotters above the top brasses. The sliding quadrant is guided at the sides by semicircular brasses clasping the main columns, and adjusted by keys and set nuts; the guidance of the upper end is attained by a bracket, secured to the entablature. The " side elevation " shows the link thrown back, or at full-stroke for starting, the quadrant and the levers being at half-stroke, the latter being indicated by dotted lines only. " The end elevation " shows the links in section, also a portion of each of the quadrants, the eccentrics being represented as keyed on the intermediate crank shaft.

FIG 68.



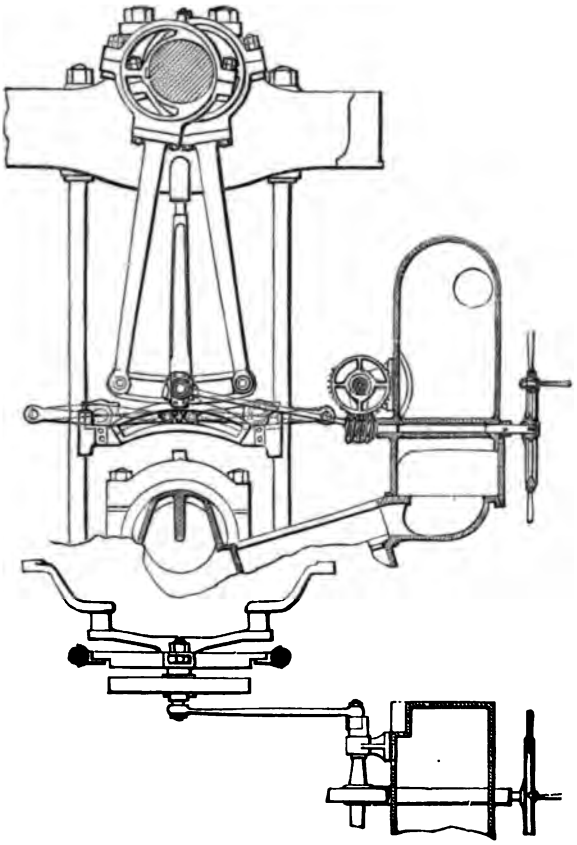
Next, attention must be given to the starting-gear. The main use of this gear is to raise or lower the slide-valves without the motion of the cranks, or steam pistons. Now, with the link motion as last illustrated, this is effected by moving the link forward or backward as may be required, which by the fixed positions of the eccentrics, causes the valves to move simultaneously. Many arrangements have been made and carried out to meet these requirements. In some cases the shifting rod is connected to a lever, the latter being keyed on a weigh shaft, to which motion is imparted by a worm and toothed quadrant. In other instances, a pinion and wheel have been preferred; while a third example omits the wheel, and the rod is connected to a shifting rack, the latter being worked by the pinion. Each arrangement, it is noticed, accomplishes the same result, although the mechanical contrivances are different from each other.

With the example on the preceding page, the arrangement of the starting gear is unlike any other just alluded to; for, the principle of the motion is a direct action, this being attained by a revolving screw and sliding cross-bar. The side elevation shows the screw supported in a frame at each end, with the starting wheel beyond the outer bearing. The cross-bar is also shown, but more clearly in the plan of the gear. The connection with the links is attained by flat rods hung at each end of the bar. In order to counteract the spiral action of the screw, and preserve a direct motion for the bar, two side guides are used, and a central slipper guide directly under the screw. It will thus be understood that, on imparting a rotatory motion to the screw by the hand-wheel, the cross-bar receives the effect, and a sliding motion is imparted, by which means the link is shifted in the desired direction. The end elevation represents the position of the wheel between the cylinders, and its height from the trunnion centres. The principle of this arrangement is used by many firms besides Messrs. Watt: for example, Messrs. Penn, Maudslay, Ravenhill, Napier, and Hawthorn have constructed and applied it for "screw" engines.

The shifting of the link, as before noticed, can be accomplished by various arrangements of the details. That just alluded to is a direct action, or a sliding motion for the actuating ends of the connecting rods. Now, while admitting that this is the correct motion, it must not be forgotten that complication for the working parts is introduced; and attendant also is the expense of manufacture and repair. To reduce those evils is the aim of all right-thinking engineers, and the firms in connection with the examples alluded to are not behind in this matter: inasmuch that they do all they can to reduce them.

For engines of small or moderate power, and where the slide valves are of light weight, and therefore easily moved, the arrangement illustrated by Fig. 69 is often preferred. This is an example of general practice by many eminent firms, one of them being the Messrs. Dudgeon, from whose working drawings those engraved were compiled and produced. This arrangement is termed the worm, wheel, and lever motion, of which the following is the description. The side elevation shows the eccentrics, link, sliding quadrant, and working levers at half-stroke; the entablature and trunnion-block being shown complete, beyond the gear. A portion only of the condenser is represented in section; but a complete sectional elevation of the discharge chamber is shown, to show the means for supporting the starting wheel shaft, which is a tube cast with the chamber, and a loose collar, secured, on the outside prevents any lateral movement. The hand-wheel is keyed on the shaft, and the horizontal projecting handle on the wheel is for the purpose of quick manipulation, when required. The shaft has formed with it, at the other extremity, a coarsely presented, which are supported by plummer-blocks—seen in the elevation only—secured to provisions formed on the cylinders. The dotted curve, seen in the elevation of the *chamber* near the quadrant, is explained by the plan: being the space requisite for the action of the working

FIG. 69.



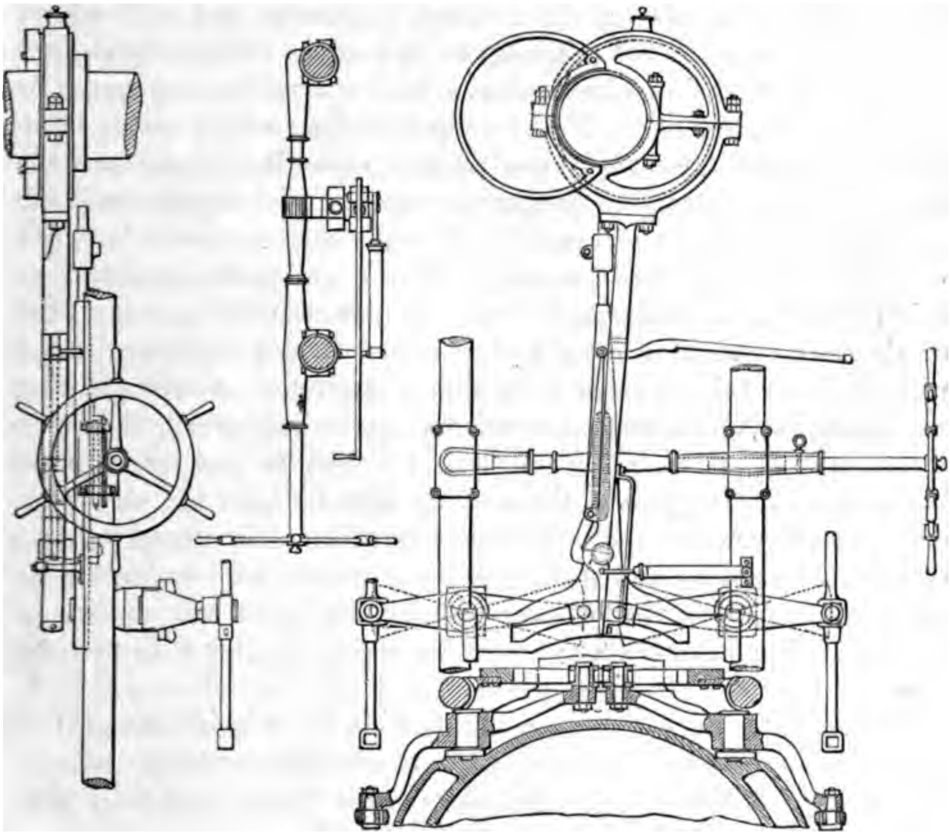
Messrs. Dudgeon's Link-Motion and Starting Gear for Oscillating Paddle-wheel Engines, as used by them and other firms, in the year 1862.

lever. The principle of this arrangement is so obvious from the illustration, that it is only necessary to state, that, on motion being imparted to the wheel, the worm acts on the toothed quadrant, and the levers, by their connection with the link, shift the same, and thus the slide valves, are raised and lowered as required.

To correctly understand any branch of science or arrangement of mechanism is first to become acquainted with the principles of the requirements: and by them the engineer should regulate all his productions: and obviously also whether one, two, or more attainments are required at once, each is alike in principle. The motion for the slide valve is a simple effect to be produced, but the main question is the best means for preventing that motion when such is desired. The link, when at half travel, brings the working levers on the horizontal line, and thus the slide valves cover the ports, but the speed of moving the valves entirely depends on the power expended to shift the links. Another fact also presents itself for notice, which is: that when the eccentrics are in a certain position the link *cannot* shift the valve to produce much effect, and thus one engine actually has to start the other. Now to obviate this, the entire *disconnection* of the slide valves from the eccentric motion is required, and thus the arrangement represented by Fig. 70 is often used by some authorities in preference to those examples having had prior notice. To fully appreciate this arrangement, the main effect must be remembered, viz., "independent means for working the slide valves." In this case the valves can be shifted to the full, or any portion of the stroke, irrespective of the angle of the eccentric or position of the steam piston, and thus the engine can be held—so to in the crank shaft, projecting beyond the periphery. Suitable projections in the boss of the eccentric bear against either pin when the rod is in gear; the direction of the rotative movement causing the constant contact of the pin and eccentric boss. On disconnecting the eccentric rod, the eccentric retains the equilibrium position—already alluded to—and remains stationary until the pin comes in contact with the projection by the rotation of the shaft, and then the engine works its valves.

FIG. 70.

End Elevation. Plan of Starting Gear. Side Elevation.



The English universal Single Eccentric Motion and Starting Gear for Oscillating Paddle-wheel Engines, as used in the year 1862, and twenty years previously, by nearly all the leading Marine Engineering Firms.

Next, attention must be given to the starting gear. Presuming the engines are to be stopped, the hand lever—level with the top of the starting wheel—is pushed towards the eccentric rod, and the lower end of the lever being cranked into a slot in the rod forces the rod from its bearing on the quadrant pin. The pin then works in the loop secured to the front side of the rod, and the cranked end of the lever prevents the eccentric rod returning to its bearing. When the engines require to be started, the hand wheel is used as a preliminary means for working the slide valves. Now, assume that the eccentric rod is disengaged as described, the working of the slide valves is independent of the eccentric. The position of the starting wheel will be as that seen in the drawing under notice; or in gear; although the eccentric rod is shown connected, which is only for the means of representing the application of this gear. On referring to the end elevation, it will be noticed that on the starting wheel shaft a pinion is secured, and this gears into a rack, the latter being secured to the sliding quadrant. Now, on turning the pinion, the rack ascends or descends, as may be required, and thus a movement is imparted to the slide valves similar to that derived from the eccentric. The plan of the starting gear, between the elevations, conveys a ready understanding as to the connection of the several portions of the details, and the sectional plan of the working gear—under the side elevation—illustrates the form requisite for the levers and position of the quadrant, and means for guiding the same, together with portions slide valves, to cause the steam to enter the cylinders at the opposite ends—the direction of turning the wheel of course determining this latter effect. On the engine starting, the eccentric rod can be set on the quadrant pin, as soon as the latter is level with the opening, and the spring—contained in the box connected to the entablature column—retains the rod in its bearing. The pinion, on the starting wheel shaft, being withdrawn from the rack on the quadrant, the eccentric becomes the agent for working the valves, without affecting the wheel.

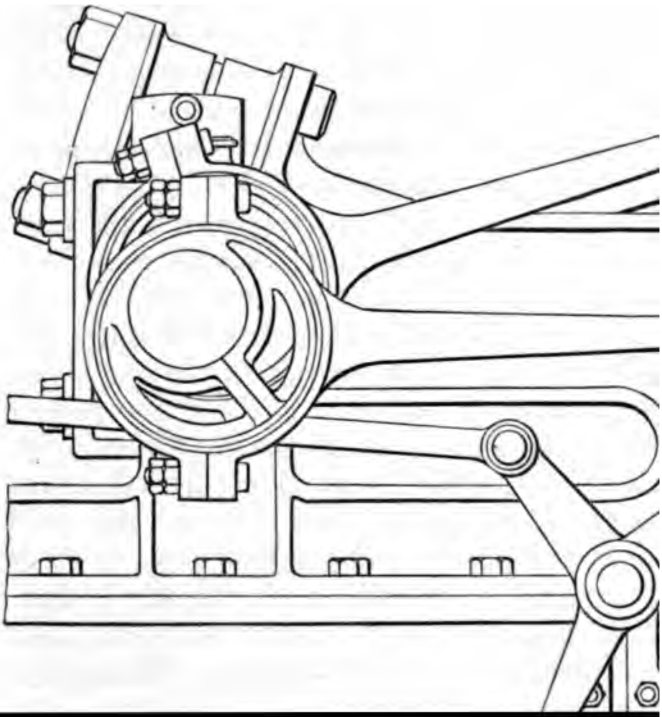
When the engines are required to be "brought up" suddenly, as in the event of a collision or any other cause, the disconnection already described occurs; and, on the starting pinion gearing with the rack, the slide valves can be instantly set at half-stroke, thus preventing any admission of steam into the cylinders, and also steam can then be admitted into their opposite ends by shifting the valves sufficiently.

The main advantage with this gear is, therefore, that the valves can be "handled" separately, at any portion of the stroke of the piston; and both pistons can be operated on by the steam equally if required, for the purpose. Obviously also, when the valves are worked by the motion of the eccentric, and disconnection is not permitted, the speed of the pistons determines that for the valves; but when hand, or separate power, shifts the valves, the admission or stoppage of the steam is more readily acquired. Large engines, fitted with the gear under notice, can be started, stopped, and reversed almost instantaneously, without over straining any portion of the gear.

It is preferred, in some instances, not to use the spring and box—for the purpose of holding the eccentric rod on the quadrant pin—but to use a lever with a catch-spring, connected to a slotted quadrant; the latter being secured to the side of the discharge chamber of the air pump—the starting wheel, in this case, being beyond the chamber. With this arrangement, the horizontal hand lever with the cranked end is dispensed with, also the slot in the eccentric rod, and the lever connecting rod is attached to the back of the loop instead of the side of the rod as in the example illustrated.

For engines of small or moderate power, or bet
power nominal collectively, the hand wheel is not
valves can be shifted by long double levers; t

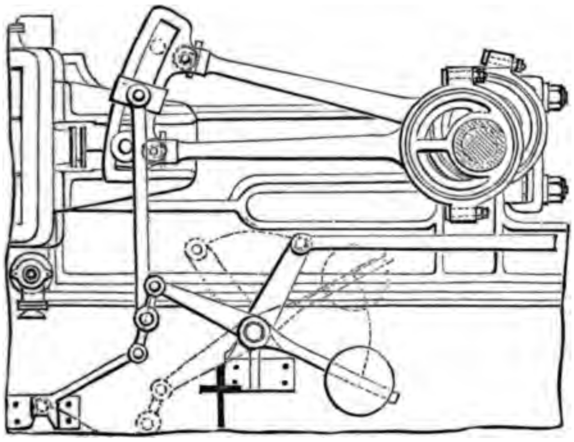
FIG. 71.



is not of much importance; but the adoption of either the "wheel" or "lever" for manipulation depends on the power requisite to shift the slide valves; the less the friction, therefore, often due to the pressure of the steam; the less the power requisite to "start, stop, or reverse" the engines.

The firms at present most partial to the arrangement illustrated on page 85 are Messrs. J. Penn and Son, Messrs. Maudslay, Sons, and Field, and Messrs. Ravenhill and Hodgson. Each of those authorities differ slightly in their notions of design, but they of course accomplish the same result in the end. The example illustrated is very similar to the practice of Messrs. Penn and Messrs. Ravenhill.

FIG. 72.

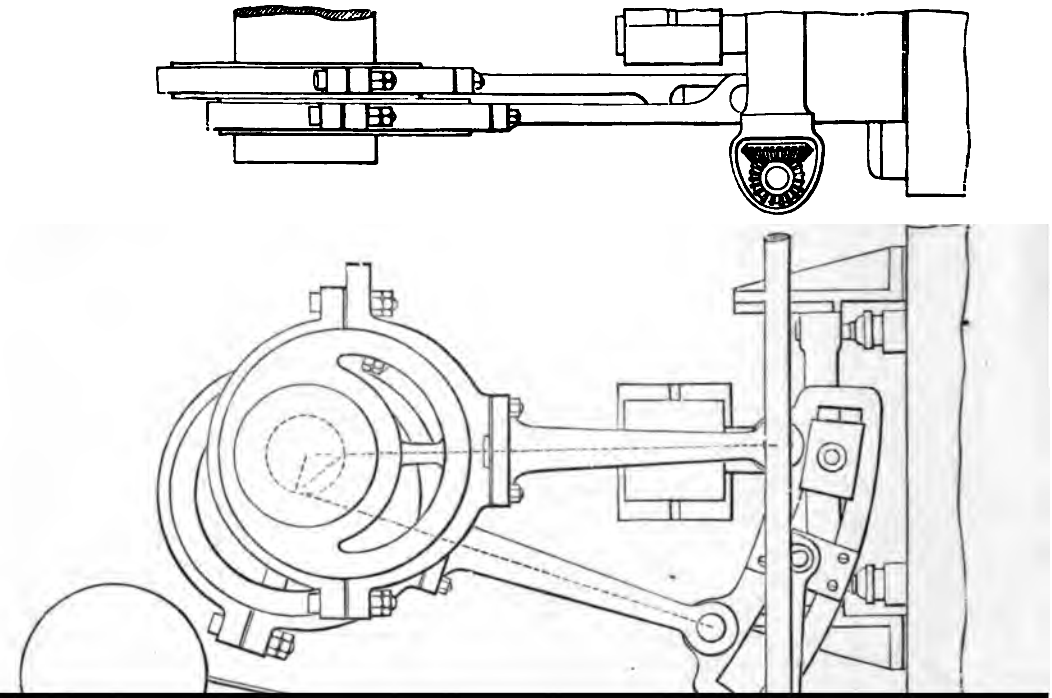


Messrs. Watt's Link-Motion for Screw Engines, with their Parallel Motion for raising and lowering the Link, as used in the year 1862.

We next explain and illustrate the best arrangements of link-motion for screw engines, as they are popularly termed, or engines applied for working screw-propellers, beginning with the arrangement by Messrs. James Watt and Co., as shown by Fig. 71; the main accomplishment of which is that the fixed end of the pin, on which the link suspension rod is secured, *always* rises and falls *vertically*, as its extremity works in the guide piece that is secured to the main frame for that purpose, and the reversing gear consists of levers and a counterbalance, worked in a similar manner, as shown by Fig. 68 on page 80.

Messrs. Watt have also another arrangement, to attain the same effect as that just referred to, which is illustrated by Fig. 72 on the pre-

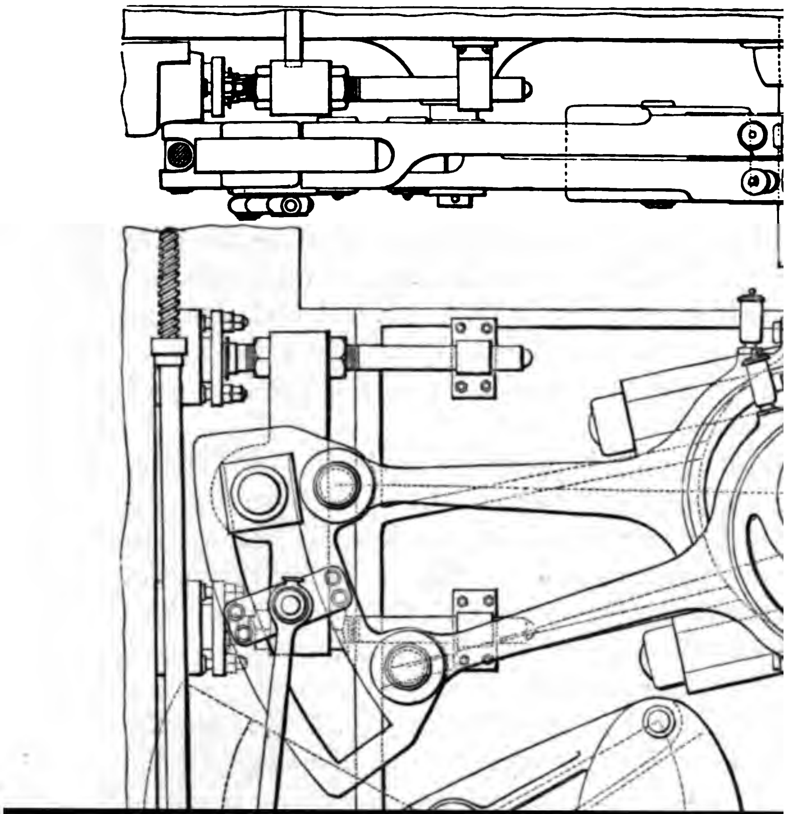
FIG. 73.



We direct notice next to Messrs. John Penn and Son's arrangement of link-motion, as shown by Fig. 73. The link is the slotted kind, the eccentric rods being connected *within* the extremities, and the suspending point is at the *centre* of the link. The eccentrics are the usual type with gun-metal bands and wrought-iron rods. The link is raised and lowered by a screwed rod receiving motion from mitre gearing on it and the hand-wheel shaft. The weight of the link, pins, rods, and sliding block is counterbalanced by the lever and balance weight below the "motion;" and thus the power requisite for shifting the slide valve is greatly reduced. It will be noticed that two valve rods are adopted, and the requisite guidance is above, below, and central of the rods, by which positions a direct action is certain. When the firm in question use a single rod for the valve rod the central guide is adopted only: of a square section across.

To be noticed next, also, as an improved example, the illustration, Fig. 74 on the next page, is worthy of record. This is an arrangement by Messrs. Maudslay, showing their experience in the matter. It will be seen that the principle of the action is nearly as that of Messrs. Penn's arrangement, but the design varies in many points. The lifting rod is connected to the centre of the link, and the rod is looped at the connection with the lever, and thus the link *rests* on the sliding block. This is contrary to the connection in Fig. 73, where the rod is connected alike at each extremity, and the link *hangs* on the connecting pin. The position of the screwed rod in Fig. 74 is behind the link, and thus the lifting rod is in advance, or two separate connections with the "balance lever;" but Messrs. Penn, it will be seen, prefer a single connection, or at the extremity of their lever. With Fig. 74 the slide rods are guided by brackets secured to the main frame—the latter being shown in the plan and elevation. The central guide for the cross bar, as seen in Fig. 73, is omitted by Messrs. Maudslay, and the block pin is fixed behind the bar, rather than nearly centrally of its width, as adopted by Messrs. Penn. Messrs. Maudslay prefer the eccentric rod and half band to be in one forging, lined with gun metal where in working contact. The counterbalance is *hung on* t

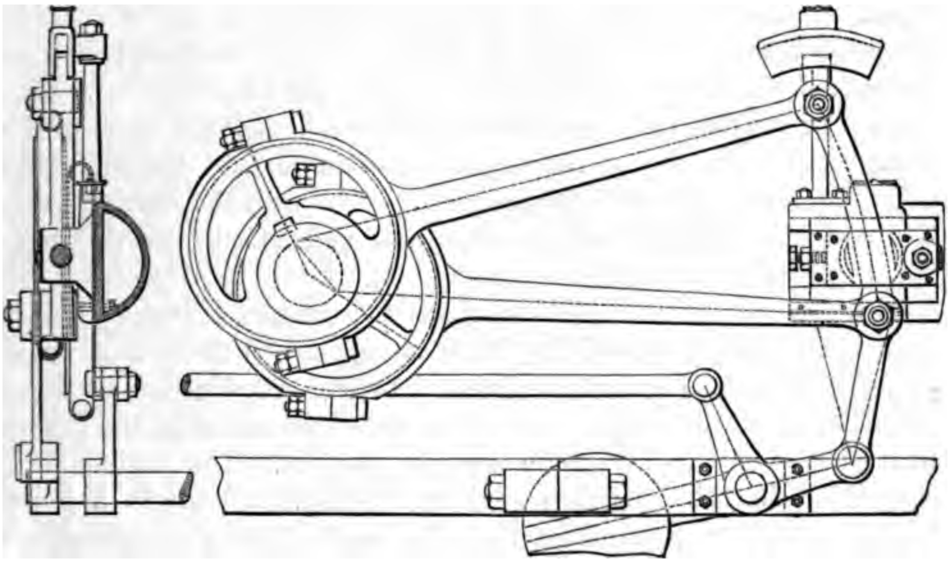
FIG. 74.



differences of opinion alluded to, both the firms have decided almost alike on the same subject.

Not long ago in the front rank of marine engineers stood the late Edward Humphrys, not only for his inventive faculties, but also for his practical treatment of any detail he investigated. The arrangement of the link-motion that he adopted was originally introduced by Mr. Nasmyth, but improved on and brought to its present state of perfection by Mr. Humphrys, as shown by Fig. 75. This arrangement consists of a *solid* bar as the link, instead of the slotted kind used by Messrs. Watt, Penn, and Maudslay. This link passes through the block, which is partially cylindrical, and the curved sides permit the oscillation required. The adjustment of the wearing surfaces is accomplished by the set stud on one side, and the slide valve rod at the other; the rod being screwed in its connection with the portion enclosing the blocks; the nut outside the plate preventing looseness of the connection. The

FIG. 75.



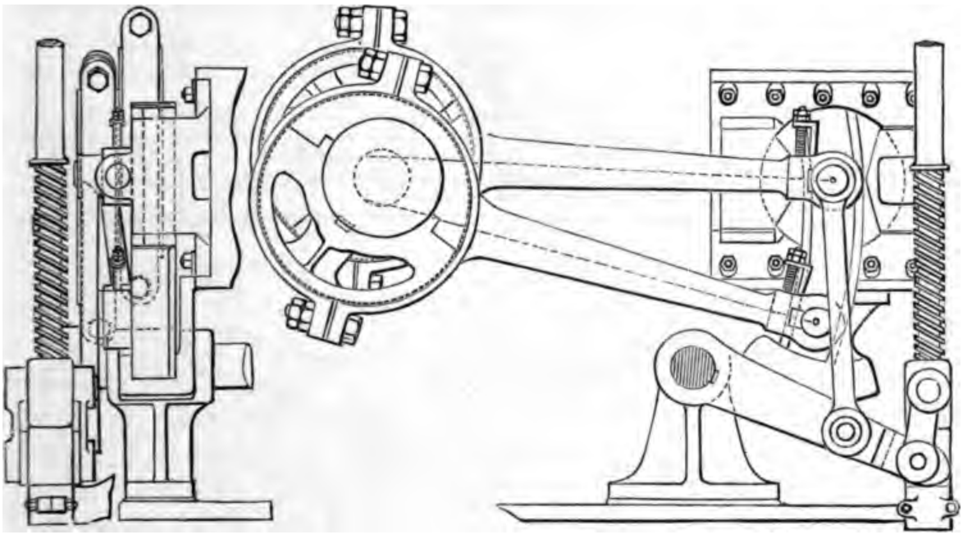
Messrs Humphrys' Solid Link-Motion for Screw Engines, with Lever Motion for raising and lowering the Link, as used in the year 1862; but was made and applied by Mr. Nasmyth to a Winding Engine in the year 1852.

sliding portion is guided in a flat dovetailed guide, which latter is a hollow bracket secured to the front of the casing; and the adjustment of the surfaces in working contact is ensured by bolts and nuts securing the adjustable or lap portions of the guide.

The guiding portions of the valve rod having been thus far explained, attention is next directed to the link and its connections. The eccentric rods are attached in the ordinary manner by being forked and clasping the link—bolts and nuts being used in the place of the usual pins and washers. The upper extremity of the link is prolonged beyond the rod's connection for the purpose of being guided when in the position shown. The guide is a curved slotted block supported on a standard or rod of wrought iron secured on the hollow bracket. The lower extremity is connected to the lifting rod, and the latter to the lever requisite to impart the required motion to shift the link; the other lever nearly vertical being in connection with the starting gear. The remainder of the details can be so well understood from the drawing, that further description is not requisite.

The firm to be referred to next, as constructors of "solid" link-motion, are Messrs. Ravenhill. Their arrangement will be understood by referring to the example illustrated by Fig. 76, together with the following description.—The link is dovetailed on one side, and passes through the block, which is in separate portions. The sliding piece supporting the block is dovetailed at the back, and fits in a guide bracket of corresponding form, the adjustment of the guiding surfaces lever is connected by two short flat rods to the *sliding* block on the screwed rod; the lifting rod being connected to the upper eccentric rod's pin. Now, on revolving motion being imparted to the screwed rod by the overhead mitre gearing, the screw block will rise *on* the rod, and, by its connection with the lever, raise the link. It will be remembered that Messrs. Humphrys guide the *upper* extremity of the link. Now Messrs. Ravenhill, it will be seen, guide the *lower* end, by the bracket secured *below* the valve rod-guide bracket.

FIG. 76.

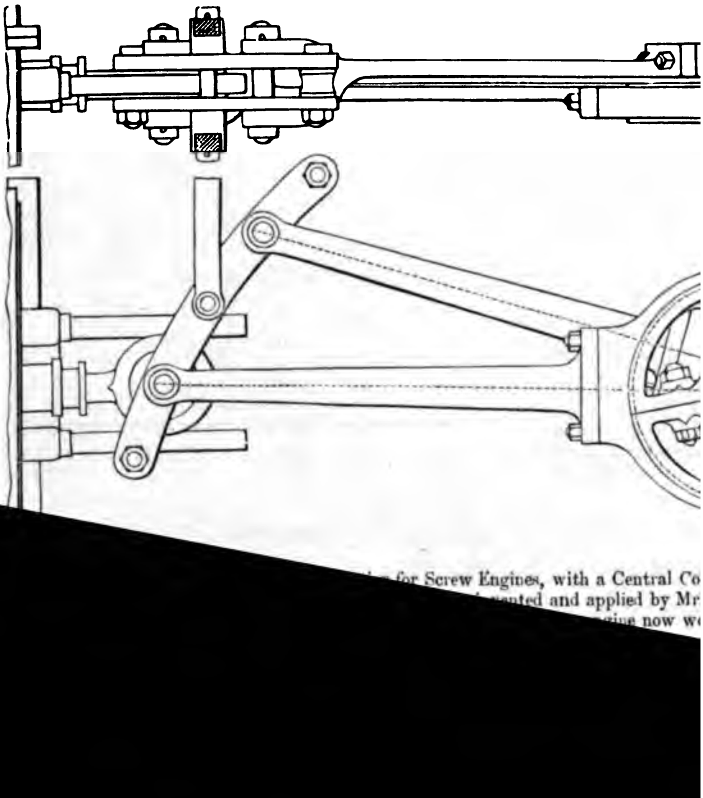


Messrs. Ravenhill's Solid Link-Motion for Screw Engines, with a Screw-Rod, Sliding-Block, and Lever for raising and lowering the Link, as used in the year 1862.

The arrangement of link-motion next to be noticed was originated by Mr. Howe, and used by him in the year 1847, and has with equal success been applied by Messrs. Dudgeon, of London, in connection with the engines fitted in the M.S. "Ruahine." This example is illustrated by Fig. 77, on the next page, and the following description will render its advantages conclusive.—The link is in two separate portions connected at the extremities by bolts and nuts. The block is enclosed in the eye of

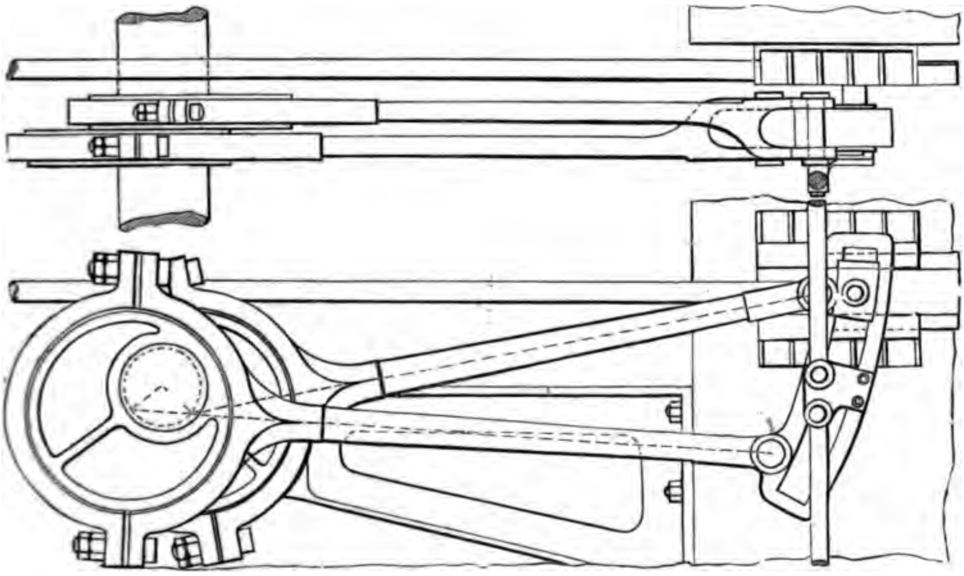
the valve-rod, and is recessed on each side to receive t
being thus enclosed in the eye of the valve rod the su
sary vibration is simply attained. The upper and lo
eye of the rod are guided by two rods above and be
into bosses formed on the casing, and thus any def
The eccentric rods are attached to the *outer* surfaces o
pins being requisite for each connection. The suspen
are connected centrally of the link, and thus an unifor

FIG. 77.



It will be remembered that with all the previous examples alluded to, the link is directly in front of the valve casing, or on the same side of the crank shaft as the cylinders. This situation is, however, by no means compulsory, for Messrs. Napier and Rennie have often fixed the valve rod-guide and suspended the link to and at the side of the condenser; the slide valve rod being prolonged to connect with the sliding piece supporting the block pin, and thus a return action results. This arrangement will be better understood by looking at Fig. 78. The

FIG. 78.



Messrs. Napier's Slotted Link-Motion situated opposite to the Cylinders, for Screw Engines, with the Slide Valve Rod *above* the Crank Shaft, as used in the year 1862.

valve rod, it is seen, is above the crank shaft—the Messrs. Rennie prefer two rods above and below the shaft—and inside the eccentric rods; the guide-block is a flat plate, bevelled at the edges, working between corresponding guide pieces secured to the side of the condenser. The link is the slotted kind, hung at the centre of its length, by the end of the upper lifting rod, the other extremity of which is attached to a sliding-screw block above the link. The lower rod is connected to a lever below, the shaft of which is in connection with the counter-balances and steam starting gear. This arrangement for the situation of the link is particularly adapted for return-action engines, where the position of the cylinders is as close to the cranks as the half stroke of piston and clearance for the connecting rod head will permit. It is also certain in its application when *long* eccentric rods are required.

The connection of the valve rod with the link is an important matter in the arrangement of link-motion, and it will be observed that only Messrs. Humphrys and Dudgeon adopt a central connection in plan for the link and slide valve rod. By Fig. 79 a mode of connecting the solid link and the valve rod is represented, as adopted by the author; the block encloses the link, and has projections on each side for support, each of which are inserted in the forked portion of the valve rod. The block is open at the front to allow the centre of the eccentric rod to be on the centre of the block both in elevation and plan. The adjustment of the wearing surfaces of the block is effected by a back plate and key ; the front sur-

Fig. 79.

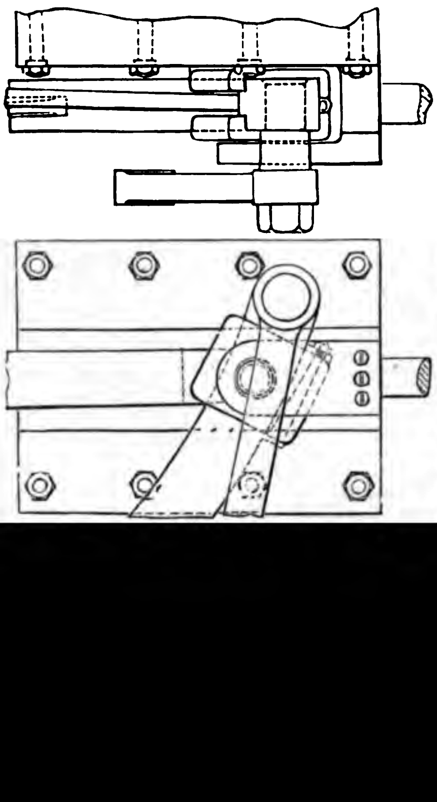
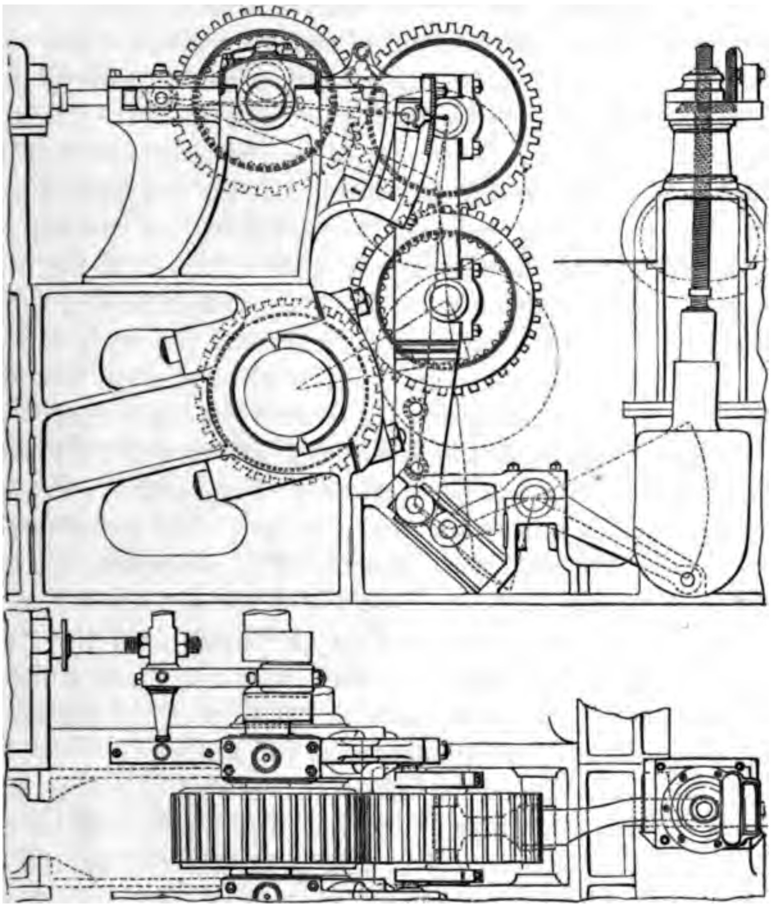


Fig. 80. The elevation shows four spur wheels in gear; two of which are fixed and the remainder loose on their shafts. The link is a *fixed* curve formed with each bracket supporting the valve cranked shaft; cranks being preferred in the place of eccentrics to impart the motion to the valves. The main, or first motion wheel is *fixed* on

FIG. 80.



Messrs. Maudslay's (Sell's patent) arrangement of Spur Gear and Stationary Link-Motion for three-cylinder Screw Engines, with Screw Rod and Mitre Gearing for reversing, as used in the year 1862.

the main crank shaft; the next wheel in gear and that directly above it are *loose* on their shafts, and the fourth wheel is *keyed* on the valve motion shaft. Now on motion being imparted by the first wheel to the second, the third and fourth wheels are respectively affected, and thus the constant motion for the valves is occasioned. To stop the engines the valves must be situated at half stroke, and this situation is occasioned by the block in the link being set at midway position. The attainment of this is, by the raising or lowering of the levers below;—the screwed rod and mitre gearing being the transmitters of motion from the hand wheel. It will be noticed that the two loose wheels are supported by the lifting rod, and the lower end of the rod is fixed to a sliding block fitted in the angular groove formed in the framing; the motions of the extremities of this rod are therefore curved at the upper end and straight at the lower. To start the engines, or rather shift the slide valves, the wheel on the valve shaft must be moved, while the lower wheel remains in gear with that on the main shaft. Now it is the constant contact of the teeth that effects this; for obviously when the main shaft-wheel is stationary, any motion given to the wheel in gear with it must cause the same to revolve, and thus the two wheels above are likewise turned around. The principle of the arrangement is therefore that the lower loose wheel is the "starting, stopping, or reversing" agent, and the wheel on the crank shaft the "driver." The arrangement of the details in plan is compact, and situated cenparts are perfectly balanced, the vibration is the least possible, and the repair, therefore, similarly reduced.

The valve gear in use with these engines was the single eccentric and rod, the former being loose on the crank shaft, with two pins in it for the eccentric to fix against, at opposite angles as required, for the forward or backward motion of the engines, as explained and illustrated on page 85, for oscillating engines.

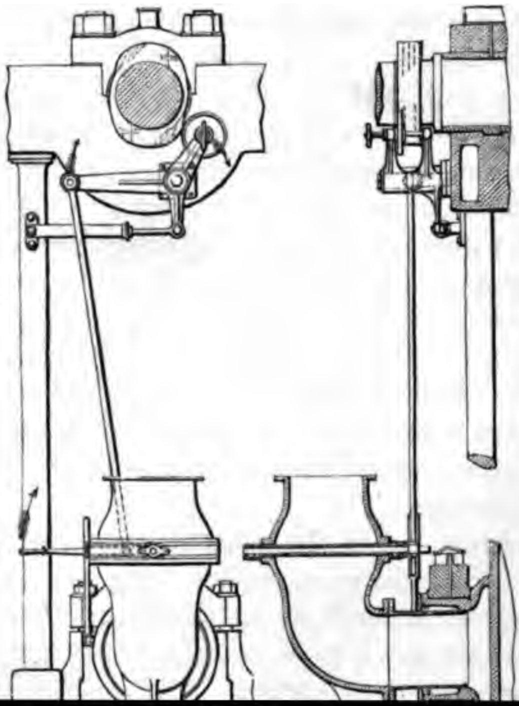
The expansion gear used was the "cam and roller" gear, which consisted of a series of cams in one casting, laid as it were one on the other at respective angles for separate purposes; and the roller was hung on a spindle, so that the roller could be regulated in position to gear with the cams, for the several grades of expansion that were provided for. This gear was used for oscillating engines also: on account of the slow speed those engines always work at comparatively with the direct-acting screw engines.

The illustration shown by Fig. 81, on the next page, is a very good example of cam-expansion-gear, as used even in the present day, but has been in general practice since the year 1840. It is represented in side and end elevations.

The side elevation shows the cams, levers, and motion at half-stroke—the steam pipe and valve casing being in front of the lever, and the trunnion plummer-block at the back. The end elevation represents the casing, valve, pipe, trunnion-block, and portions of the cylinder and lower frame in section. The expansion gear is shown complete, also the cam, but the entablature is shown half in section, and in complete elevation in the side view.

The action of the gear will be thus understood. The arrangement, seen in the side elevation, is a series of cams of unequal forms or curves: which are for the alteration of the grade of expansion when requisite. The motion of these cams is imparted to the throttle valve by a series of levers. These levers are cast together with one boss, thus forming a "carriage," the shaft of which is secured to the entablature. The perpendicular lever connected to the spring box, is always pushing towards the opposite column, and thus the roller, that is hung on the pin of the angular lever, is when in gear pressing on the cam; therefore the cam, when revolving, causes the horizontal lever to rise and fall. The connection of this lever with that on the throttle valve spindle,

FIG. 81.

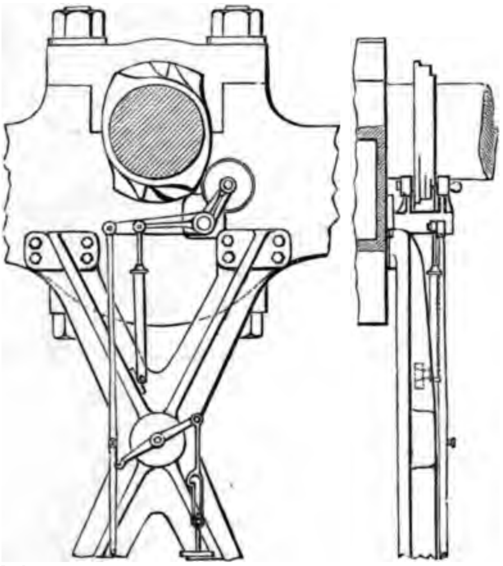


the cam be required to revolve without affecting the valve, the roller can be thrown out of gear by the handle, and the whole of the levers will be held in the direction indicated by the arrows; the set screw rendering their position stationary. When the grade of expansion is required to be altered, the hand-pin,—on which the roller is hung, seen in front of the cam in the sectional elevation,—is turned to shift the position of the roller opposite to the required cam. The spindle is screwed in the present example, and a set-nut outside the boss retains the required position.

When "cross frames" are used as well as, or in the place of columns, the gear is arranged as shown by Fig. 82, which is the side and end elevations of the gear and its connections, minus the throttle valve and levers below, as shown in the previous example.

These two arrangements are very popular both in England and Scotland with the leading marine firms.

Fig. 82.

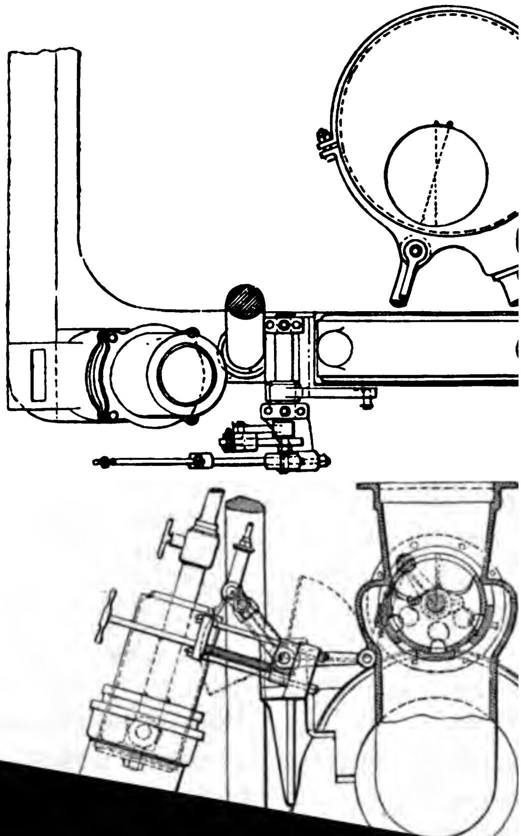


Ordinary Expansion-Gear for Oscillating Paddle-wheel Engines, as used by the leading Marine Firms in the year 1862, and for thirty-five years previously for Side Lever Engines.

The next example which deserves attention as a simple and effective arrangement, is that generally adopted by Messrs. Maudslay, Sons, and Field; this firm prefer the form and arrangement of the details as illustrated by Fig. 83, on the next page. The side elevation shows the valve and casing in section, and the gear complete behind the casing—the relative position of the gear will be better understood by referring to the plan. The eccentric, shown in elevation above the plan, is of the ordinary kind with a hoop or band, having three rods connected to its lower side. One rod, it is seen, is connected to the gear under notice and the remaining two to the feed and bilge pumps plungers only shown in the elevation and plan of the arranger

The valve is cylindrical, with openings for the adm

Fig. 83.



shell of the casing correspond with those in the valve, and the widths of the solid portions of the latter determine the laps required. After the steam has passed through the valve, it flows into the passage in the casing, and from thence into the trunnion opening; the valve and casing being of such a simple character, that the sectional view only is deemed requisite to illustrate them.

The motion required for the valve is obviously vibratory, to admit and intercept the steam, which is attained by the rotary motion of the eccentric. The connection of the latter to the valve spindle is by a series of levers, with separate shafts and connections. The motion from the eccentric is transmitted in the following manner.—The rod attached to the eccentric band is connected to the first motion lever—shown at an angle—a second lever being shown on the horizontal line. This last—or second—lever transmits its action to a third but shorter lever, which is keyed on the valve spindle; the connection with this lever being attained by an adjustable rod.

On alluding to the plan, it will be seen that the "first lever"—seen in the elevation as one—is actually two levers at the same angle. The front portion is secured on a pin, and the back part separately secured on a shaft, supported by a bracket cast with the trunnion plummer block. Inside the first bearing is the "second lever"—horizontal—in the elevation.

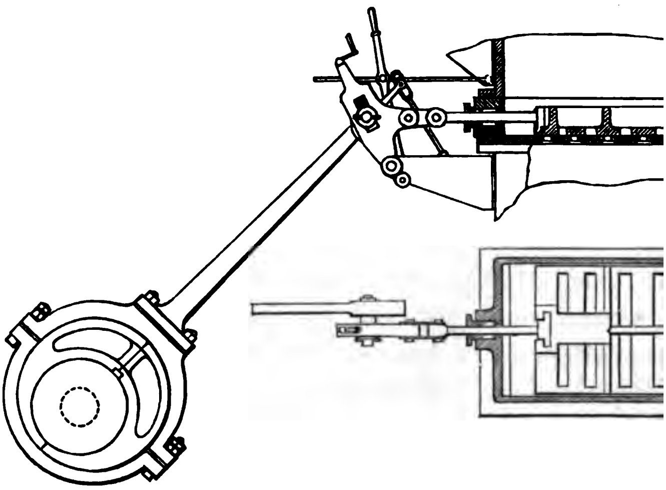
Obviously, from this connection, on the eccentric causing the first lever to descend, the second lever will ascend, and the third lever and valve will oscillate, due to their position on the spindle.

Thus far the motion is rendered apparent; further attention is now requisite to understand the mode of regulating the grades of expansion, to which the remaining portion of the gear—not yet alluded to—pertains. Forming a portion of the bracket alluded to, is a projection for the purpose of supporting two guide rods, angularly situated, and sustained at the extremities by a cap and nuts. Clasping the rods, at the back end, is an adjusting block, the motion for which is acquired by a third rod screwed between its bearings, and prolonged beyond the

cap with a cross-handle. The two levers before a
gether the "first motion lever," are attached tog
portion at the extremity of the inside lever, the
tion with the shaft, remaining laterally fixed, whil
common with the action of the block.

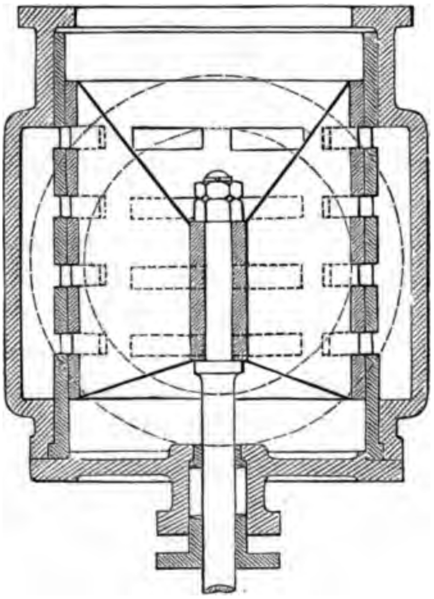
The dotted angular lines and arcs denote the
when the block is in the position illustrated.
the "first lever"—by shifting the block—the
eccentric being unalterable, the motion of the "

Fig. 84.



Messrs. Penn's Expansion-Gear and "Gridiron" Sliding-Valve for Screw Eng paddle-wheel engines, we will now refer to the best example for direct-acting screw engines, commencing with Messrs. Penn's arrangement, as shown by Fig. 84, on the preceding page. The expansion valve is the "gridiron" type, sliding on a seating of corresponding form; both being shown in side section and plan, further allusion is scarcely requisite. With reference to the "gear," it consists of an eccentric as a prime mover, and the rod is in connection with a slotted lever and sliding-block at the other extremity. The pin is fixed in the sliding block, that is contained in the grooved portion or link, supported by the bracket at the front of the casing. The cranked handle, above the projection over the groove, is fixed on the screw-rod passing through the block, thus the eccentric rod pin can be shifted in the groove when required, to suit the grade of expansion settled on. Suitable means for disengaging the rod and retaining it out of gear is ensured by the loop, guide rod, and hand lever shown above the bracket. The valve rod is connected by flat bars and pins to the link, and guides are obviated by the sufficient strength of the rod and shortness of the stroke.

FIG. 85.



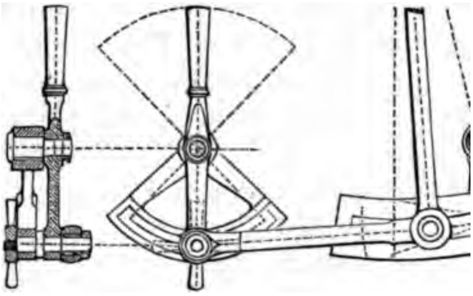
Messrs. Rennie's Sliding-Equilibrium Cylindrical Perforated Expansion Valve, Seating and Casing, for Screw Engines (similar to Atherton's, Fig. 29, page 32), used from the year 1853 to 1862.

Messrs. Watt, Napier, Humphrys, Ravenhill, Laird, and Maudslay now adopt, in most cases, the valve and gear nearly as those by Messrs. Penn, at least if not in design, the same in principle of effect and arrangement.

The firm next to be alluded to, who also adopt the principle of this arrangement, are the Messrs. Rennie; but in the place of a gridiron valve, a tubular, perforated valve is preferred, with a seating to correspond. This example is illustrated by Fig. 85, and

shows that two tubes—one within the other—c
seating, and the difference in the widths of th
portions between, produces the "cut-off" requisite
and down, and derives its motion from an ordina
change of the grade of expansion is effected by a li
attached to the valve rod. To understand the
details readily, will be to refer to Fig. 86, which

FIG. 86.

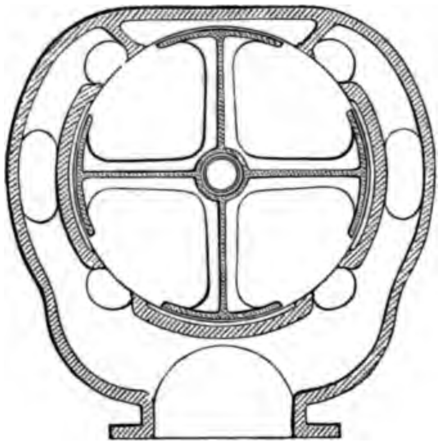


Messrs. Rennie's Expansion-Valve Link-Motion worked by
for the form of Valve shown by Fig. 85.

link, eccentric rod, adjusting handle and quadr
rod is also shown at half stroke situated centr
link—the dotted lines on the quadrant depicting
effective or neutral, as required. The lever,
link, is keyed on a portion formed with the li
balance obviates the weight of the valve and

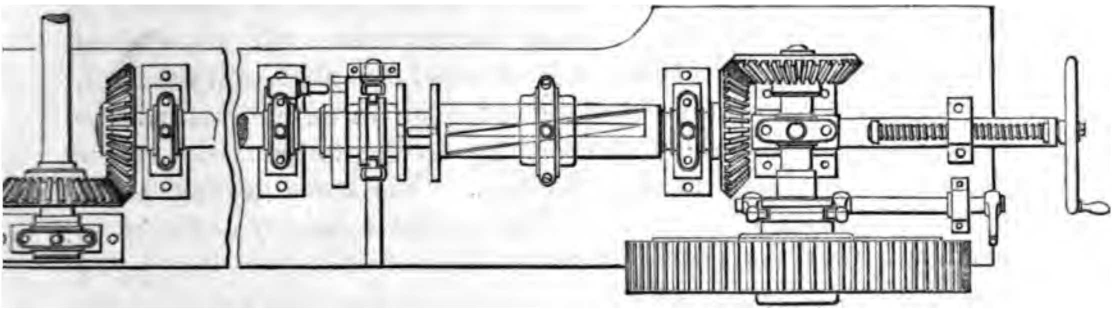
the valve, by which difference a variable cut-off is effected. The required motion is derived from the engine shaft, and transmitted to the valve by spur, mitre, and bevel gearing. One of the spur wheels, and the entire set of mitre gearing is illustrated in plan by Fig. 88. It will be seen that the counter shaft has fitted on it, between the bearings, a clutch coupling, with discs on each side of the clutch; one of the discs, when in gear with the *fixed* pin, holds the valve stationary; and the other, when coupled with that opposite, shifts the valve. As the latter attainment causes the grade or cut-off, it will be requisite to further explain the same. On the counter shaft, between the bearing and the coupling, is a *curved* grooved barrel, encompassed by a loose ring or boss fitted with a pin, which passes through the slot in the barrel and fits in a *straight* groove in the shaft. On the right hand of the mitre gearing is seen a hand wheel and screw, which latter is con-

FIG. 87.



Messrs. Maudslay's Cylindrical Revolving-Expansion-Valve, Seating, and Casing, for Screw Engines, used from the year 1840 to 1862.

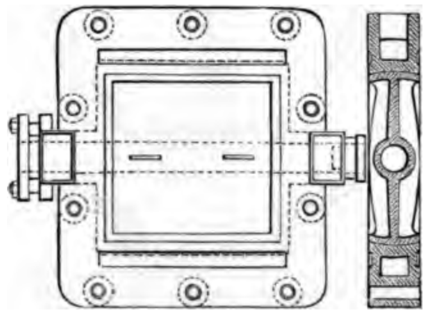
FIG. 88.



Messrs. Maudslay's Expansion Valve Gear for the Valve as shown by Fig. 87.

nected to the sliding boss on the barrel. Obvio being imparted to the hand wheel, the boss will ad the barrel will be turned in a corresponding dir needless to add that the *pitch* of the curve c barrel is the main consideration in proportion valve to produce the several grades of expansion.

Fig. 89.



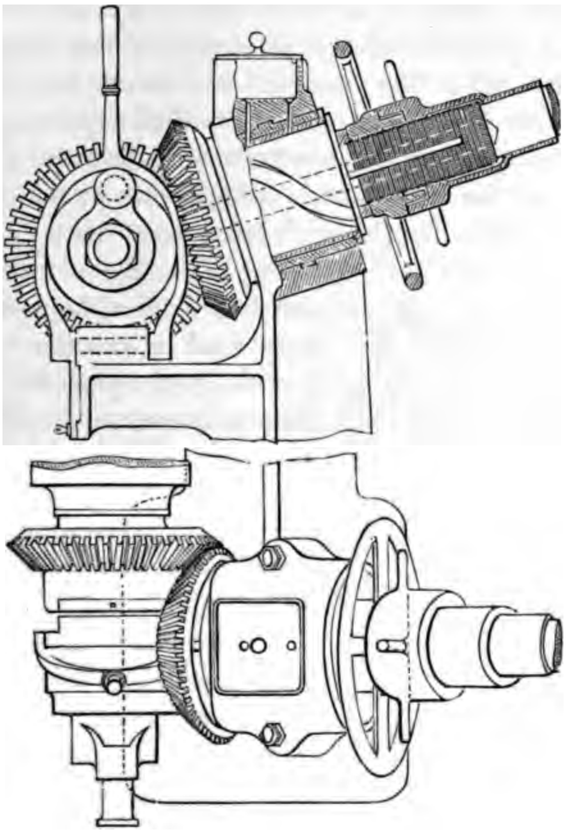
Messrs. Ravenhill's Expansion, Revolving-Flat-Valve for Screw Engines, as used in the year 1862.

Messrs. Ravenhill have also adopted mitre g gear, but the va tubular, is s flanges—the w tioned to the speed of the val pansion. The valve, and the both details, as

The arrang ing is simply lows:—on the shaft is secur counter shaft—with a wheel at each end—impa wheel on the valve spindle;—a plan and eleva depicted by Fig. 90. The alteration of the effected by a *grooved* barrel, situated directly bel on the angular counter shaft. A hand wheel is

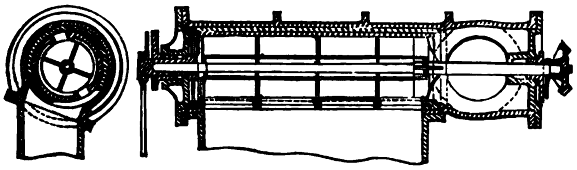
Now Messrs. Watt accomplish a similar result by shifting the *seating* on its axis, the valve being the tubular kind, as shown by Fig. 91.

FIG. 90.



Messrs. Ravenhill's Expansion Gear for the Valve shown by Fig. 89.

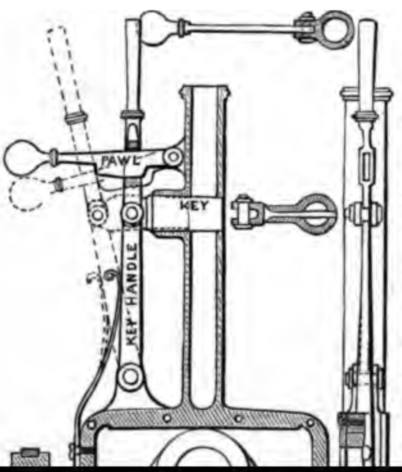
FIG. 91.



Messrs. Watt's Stationary-Equilibrium Expansion Valve, with a *Revolving Seating*: for Screw Engines, used in the year 1862, and thirty years previously.

The valve has two ports nearly opposite each other, but the openings in the seating are divided by narrow bars. The seating is supported within the casing, and the valve by the spindle in the centre. The bush that passes through the stuffing-box is connected to the seating by an internal coupling at the extremity of the same; and by the handle on the bush, the seating can be shifted around in the required direction to alter or set the grade of expansion. The motion for the valve being rotary, mitre wheels with the requisite counter shaft are used—one of the mitre wheels being shown at the extremity of the valve's spindle; those for the shaft being omitted.

FIG. 92.



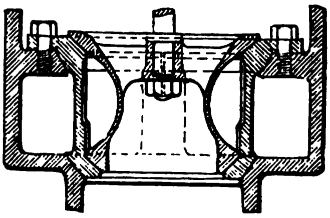
Our remarks next refer to the valves and gear for land beam-engines, such as were used about the year 1862, for "winding, pumping, and blowing," and other requirements. For engines of small size, whether condensing or non-condensing, the ordinary eccentric motion and slide valve were used, as is indeed often at present; but for large engines, particularly for pumping, without the fly-wheel, the old Cornish valve-gear, as illustrated by Fig. 4, on page 10, was still adopted, and is used now with detailed improvements according to of beam engines. Amongst the general rotary cam motions, that arranged by ourselves may be referred to, as illustrated by Fig. 92.

The cam revolves with a shaft driven by mitre gearing, and the casing is a gun-metal box as deep as the cam is long and as wide as twice the radius of the end or main curve of the cam. The exhaust valve rod is keyed in the socket below the box, and the supply valve rod is loose in the long socket above the box when out of gear, and when in gear for working the engines, the disengaging key is inserted through it, as shown in full lines; the dotted position representing the key out of gear or for stopping the engine.

By this simple arrangement for disengaging the supply valve from the motion of the cam, engines of the largest power can be handled with one hand; because the little pawl when down keeps the key out of gear, and on lifting the pawl the spring in front of the key-handle drives it in; and an ordinary marine starting wheel, with suitable handles, on the cam shaft turns the cam separately when required, so as to start the engine exceptional to the mitre gearing, and similarly to reverse or stop it also.

The steam valve, seating, and part of the nozzle casing are shown in section by Fig. 93. The valve is scarcely equilibrium, as the top seating is a little larger than the lower, and a spring was used to counteract the unequal action of the steam on the two areas. The steam passed through the body of the valve before it entered the cylinder, and thus the valve readily closed when required. One cam was used to work each supply and exhaust valve for the opposite ends of the cylinder, by which arrangement those valves were side by side—top and bottom.

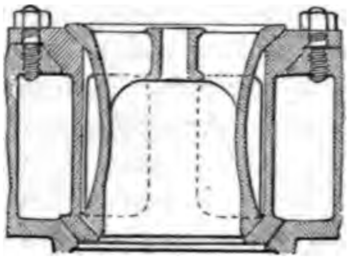
FIG. 93.



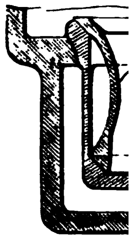
Burgh's ordinary Cylindrical double-seat Steam Valve and Seating for Beam Engines, applied in the year 1862.

In another instance we used the supply valve as shown by Fig. 94, on the next page, but the steam surrounded the valve in this case between the seatings before it opened, and therefore by its shape also a more equilibrium action was permitted. The exh

FIG. 94.

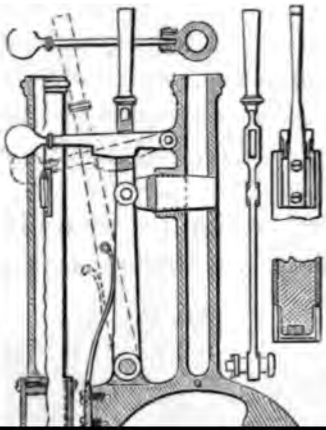


Burgh's nearly Equilibrium Cylindrical double-seat Supply Steam Valve and Seating for Beam Engines, applied in the year 1863.



Burgh's Equil
Exhaust Stea
Casing, for B
1863.

FIG. 96.

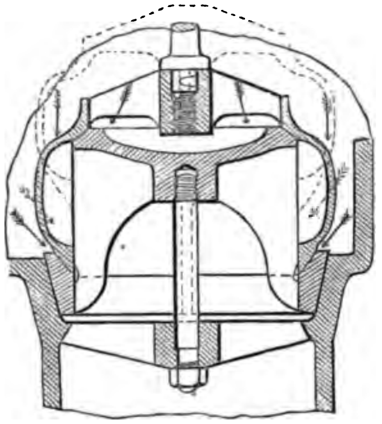


by Fig. 95. The bo
closed, and the steam p
before it is opened.
supply and exhaust
other, top and bottom
of right and left as pr

The gear that we
these last two valve
which from the cra
motion to a cam sh
by two standards; but
engine and required t

smaller and larger seats are reversed to those previously illustrated, but the non-equilibrium action of the steam is the same in effect, because the relative diameters of the seatings are practically coincident. For example, in the previous valves the lower seat portion of the valve passes through the *inner* diameter of the upper seat; but in this case the lower seat portion of the valve surrounds or encloses the *outer* diameter of the upper seat, so that the unequal areas for the action of the steam is the same in both cases. As this valve is shown closed in full, and open by dotted lines, its utility can be readily understood without further description.

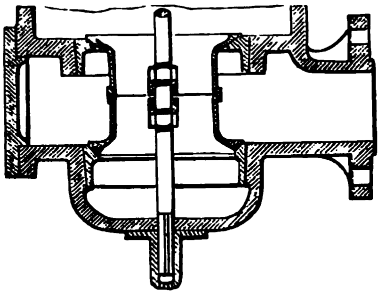
FIG. 97.



Original Cornish Equilibrium Cylindrical double-seat Steam Valve and Seating for Beam Engines.

In order to obviate the non-equilibrium action of those valves, we designed and applied the valves as shown by Fig. 98, which eradicated all the errors of the others, and proved to be of proportionate value as an attainment in practice. We made our new valves in halves of *equal* diameters, by which the seats were identical, and bolted the halves together centrally by nuts on the motion rod. By this arrangement we had a twofold advantage, which was, that the supply and exhaust valves could be made to close and open by the action of the steam, or *vice versâ*, while springs could be used, if preferable, to keep the cam box on to the cam face, if the seats of the valves were perfect duplicates, which of course in the other cases they were not.

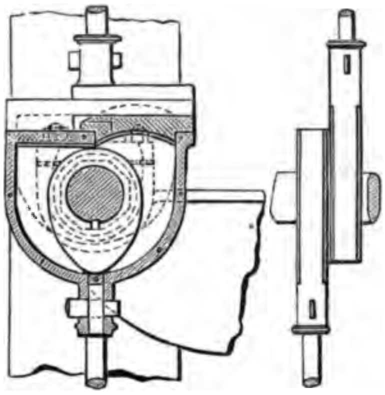
FIG. 98.



Burgh's perfectly Equilibrium Twin Seated Cylindrical Steam Valves for Beam Engines, designed and applied in the year 1863.

The valve gear we used was the unevenly-curved cams; the shaft on which they were keyed being driven by mitre gearing from the main crank shaft, and the cams were enclosed in a box or case of peculiar, but particular form, applicable for the grade of expansion, sudden cut-off, and release, with perfect exhaustion and ample lead. An illustration of this gear is shown by Fig. 99, so that it can be easily understood.

FIG. 99.



Burgh's Rotary Cam Motion with Expansion Curves for the Cam and Case, subject to the Lead, Cut-off, time for Expansion, the point of Release, and time for Exhaustion, applied in the year 1863.

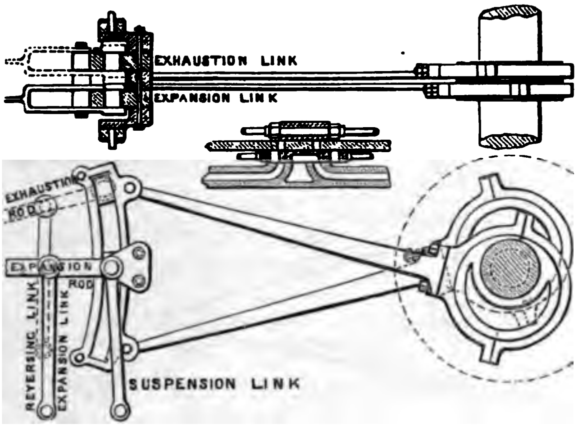
The exhaust and supply valves are side by side at the ends of the cylinder. The main advantage in this arrangement is that we could, and did, adjust and shape the cams—as they were separate for each valve—for any grade of cut-off, lead, or release, as we thought fit to experiment with, for the economical use of the steam in after practice.

At the beginning of the period we last referred to, Mr. J. F. Spencer brought out his new single-eccentric twin link-motion, which consisted of two distinct links placed side by side, and connected together so as to form double links to two eccentric rods worked by two eccentrics fixed on the crank or other shaft, so that one eccentric rod is attached to one end of the exhaustion link, and the other to the other end of the without in any way affecting the efficiency or action of the exhausting valves; or the exhaustion of the steam.

For stationary engines or engines that do not require to be reversed, two eccentrics with rods and only one single link are used, and the exhaust valve rod is connected to one end of the link only, while the steam or expansion-valve rod slides on the link to vary the cut-off.

The illustration, Fig. 100, is a side elevation and plan of the gear, with a section of the slide valves and cylinder ports and passages. The links for working the main and expansion valves are identical; the upper eccentric rod is for the back gear or motion; the lower rod is for the fore gear. Between the link and the valve rod the upper radius or connecting rod, as shown by dotted lines, is for the exhaust; whilst the lower or horizontally placed radius or connecting rod is for working the expansion valve. The double fixed link is held in position or supported by a vibrating rod, whilst the reversing is effected by a compound weigh shaft, formed by a tube surrounding a solid shaft. The positions of the reversing lever and expansion lever as operating upon their respective link blocks are also shown.

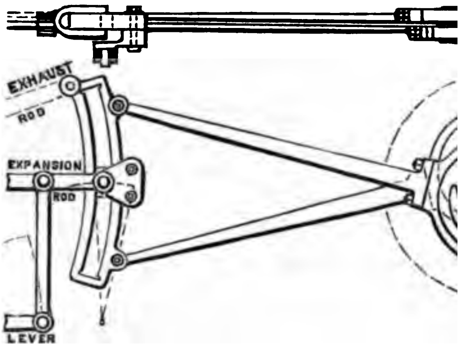
FIG. 100.



Spencer's Single Eccentric Twin Link-Motion for Reversing and for Working the Main and Expansion Valves; also shown in Section, with the port plate between them, patented in the year 1863.

The illustration, Fig. 101, is a side elevation a having a single fixed link and two eccentrics of different amount of travel for the valves; both ec set for forward motion; the expansion rod wher admission, and when down for a minimum admis the horizontal rod, situated between the link expansion radius rod; whilst the rod in dotted angle and above the expansion radius rod, conne the slotted link, is the exhaustion radius rod.

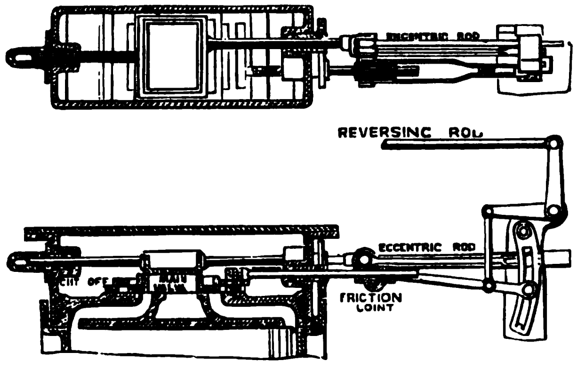
Fig. 101.



Spencer's Twin Eccentrics, *fixed* Link-Motion for work
and Expansion Valves, patented in the year 1

the eccentric the upper rod may be assumed as h which, unlike other arrangements of this class, had the link separately situated directly in front of the valve casing instead of being formed with the band of the eccentric; thus reducing the details in comparison with the double eccentric order, and supposed to accomplish a similar effect as the double link. The illustration, Fig. 102, is a sectional elevation and plan of the valves and gear. The cut-off valve is made to work on the back of the main slide valve, which is so formed as to have its flanges produced with two ports or openings therein. The cut-off valve has also its flanges produced with two ports similarly, one of which always coincides with one in the main slide valve at the extremities of its stroke, while the other port is closed. The main valve is worked in the usual way by an eccentric rod and valve rod, and the latter may be, for convenience of arrangement, carried through the back of the valve casing or chest, as shown. The cut-off valve may be also worked from the back of the casing or valve chest, but in the illustration they are both represented as being worked from the front of the valve casing, the cut-off valve being also worked by a rod—both the rods being side by side. Upon this rod is mounted a friction sliding joint that is worked by the slot link, which is suspended from a fixed centre. This slot link is actuated by a connecting rod from the main valve-

FIG. 102.



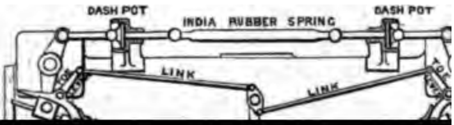
Brown's arrangement of Cut-off and Main Valves, with a Single Link and Eccentric Motion, patented in the year 1863.

rod joint, and by this arrangement the speed
travel assigned to the cut-off valve varies with
working block in the slot link, but as the trave
back of the main one is just sufficient to close on
time open the other—this amount of travel being
of the abutting surfaces of the two valves—anc
when effecting any degree of expansion, must ha
amount of travel than that of the main valve
joint moves freely on the spindle after having clo
port, and thus the steam is regulated.

On page 54, by Fig. 48, is illustrated peculi
cylindrical valves for regulating the admission, expa
of the steam into and from the cylinder of an eng
the arrangement of the gear for that purpose.
gear is similar to the "Corliss" valve gear inve
in America about ten years ago by a native o
since been introduced and very much improved b
this country, and also in Scotland.

The illustration, Fig. 103, represents a side

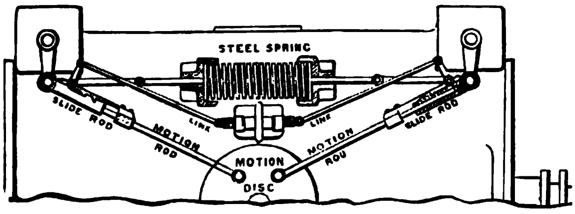
Fig. 103.



as applicable for working steam admission valves, when—as in the "Corliss" engine—such valves are arranged to close by the action of weights or springs. This arrangement consists in substituting india-rubber springs or spiral steel springs for the weights or blade steel springs hitherto used in America, the object being to avoid noise and liability to breakage. The admission valves of the steam cylinder are actuated by rocking spindles having levers on their ends. The lower ends of these levers are actuated by motion rods from the rocking disc, which last is worked by the eccentric rod, and which, by the rods, also actuates the levers of the exhaust valves. The upper ends of the admission valve levers are linked to discs, which work in the dash pots, used with this class of valve to prevent concussion. The dash pistons are formed with spindles which work through the backs of the dash pots, and are connected together by the india-rubber spring, one spring thus serving for both valves.

By Fig. 104 a spiral steel spring is shown as applied in a similar way as the india-rubber, excepting that it is connected to the same ends of the valve levers as the motion rods are, and it reacts expansively, whereas the rubber spring reacts by contracting.

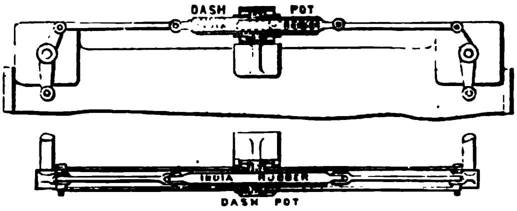
Fig. 104.



Inglis's "Corliss" Valve Gear, with a Steel Spring and two Dash-pots to close the Cut-off Valves, patented in the year 1863.

Fig. 105, on the next page, is sections in plan and elevation, showing another way of applying an india-rubber spring, the two dash pots being in this case formed in a single casting placed centrally, and the springs being placed in a central tube, within which the dash pistons can work. In this class of engine the steam admission valves are opened against the resistance of the springs or weights, and the closing is readily caused—when giving steam through only part of the stroke—by releasing or disconnecting the parts.

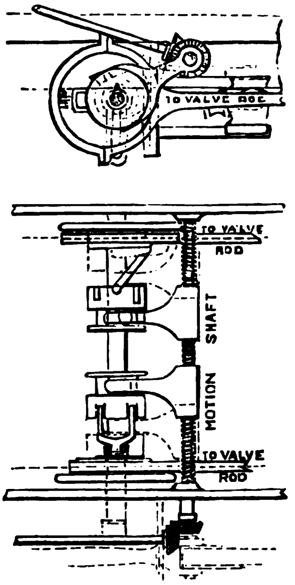
FIG. 105.



Inglis's "Corliss" Valve Gear, with an India-rubber Spring and Twin Dash-pots in one casting for closing the Cut-off Valves patented in the year 1863.

In Figs. 103 and 104 are shown also two modifications of improved adjustable releasing gear, forming part of this arrangement. In the modification shown by Fig. 103, each rod has jointed to it a catch, acted on by a spring, and arranged to lay hold of the block jointed on the pin of the valve lever, and also to slide on the end of the motion rod. The catch has jointed to it a toe lever or bell crank, which bears on the block, and lifts up and releases the catch at the proper time. The toe lever is connected by a link to a lever, adjustable by the governor rod, or it may be by hand. It will be seen that the relative motions of the parts will cause the release to take place at an earlier or later period of the stroke, according to the adjustment of the lever to which both links are jointed. In the modification shown in Fig. 104, with its motion, the requirements of perfect valve gear would be accomplished, as illustrated by Fig. 106.

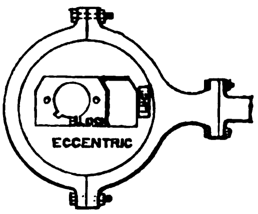
Fig. 106.



Taylor's Shifting Eccentric Valve Gear as applied to a Locomotive Engine, patented in the year 1864.

The eccentric, illustrated by Fig. 107, according to this arrangement, is mounted on a block or centre piece keyed on the crank shaft, or it may be on an additional eccentric shaft, the eccentric being so fitted thereto as to be rigidly carried round with the block, but also that it may be slid in the direction of its diameter, or nearly so: it is supported on either side by cheek plates from the block. From the eccentric strap a connecting rod leads direct to the valve rod as in an ordinary fixed eccentric. At a little distance from the eccentric block is placed a piece somewhat resembling the sliding part of a shaft clutch, and like it sliding on the shaft, but carried round by a feather, and having a groove around it, to which the ends of a forked arm clasp, for the purpose of sliding it towards or from the eccentric; on the side next the eccentric the sliding piece has a central boss or projection, which is embraced by the forked end of a link jointed thereto; the other end of this link is extended towards the periphery of the eccentric, near which it is attached by a joint pin to suitable lugs projecting on the side of the eccentric. When the sliding piece is at its farthest distance from the eccentric, the connecting forked link assumes a position at about an angle of forty-five degrees to the centre line of the shaft, but when moved closer to the eccentric it approaches towards a right angle thereto. The traverse of the sliding piece on the shaft produces this effect, and at the same time causes the eccentric to traverse somewhat in the direction of its

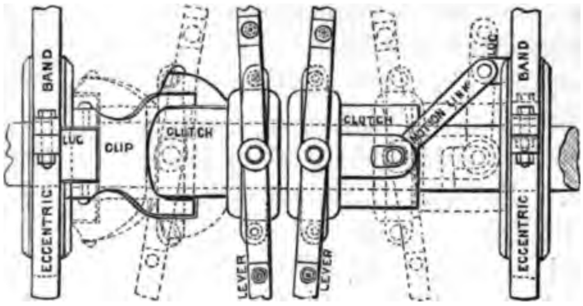
Fig. 107.



Detail of Taylor's Shifting Eccentric, patented in the year 1864.

diameter, and to transfer the point of greatest eccentricity from one part of its circumference to another, and so produce a corresponding change in the position of the valve with which it is in connection. This is shown in two positions by Fig. 108. Instead of moving in a direct line the eccentric may move in a curved course on its supporting block, which may be desirable to give the requisite lead—at all points of the traverse—to the steam when the engine is moving in one direction or the other, and to give the desired lap to the valve to work somewhat expansively.

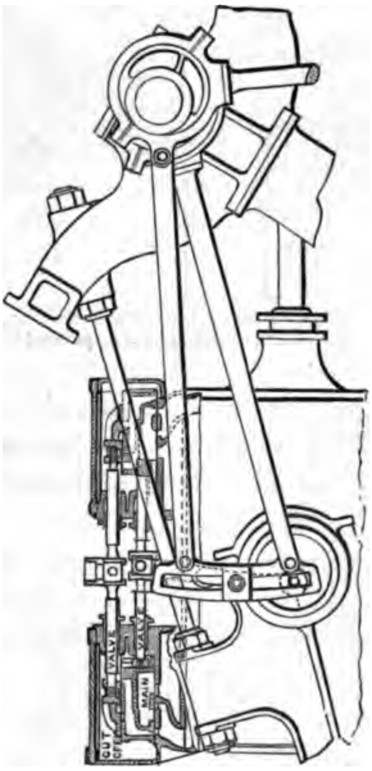
Fig. 108.



Taylor's Shifting Eccentric Valve Gear, shown in two positions at right angles with each other, patented in the year 1864.

To actuate the sliding or fork block before mentioned, the motion shaft, as shown by Fig. 106, is used parallel with the eccentric shaft with a right and left-hand screw upon it, and on each screw is mounted the forked arm before mentioned—one for each eccentric—and by paddle-wheel marine engines, worked by high and low pressure steam, the areas of the cylinders being arranged in accordance with the difference in the pressures. The arrangement of the valves and gear is shown by Fig. 109, as arranged for an *angular* oscillating engine. The main slide valves on the cylinders of this engine are worked by one motion shaft, the one end of the lever of which is brought out by a bend to the centre of the trunnion of either the large or small cylinder, and is directly acted upon by an eccentric or other means from the main shaft, without being transmitted through a quadrant or sweep, such as is used in ordinary oscillating engines. The other end of the said lever is connected direct to the valve rod when the cylinder is arranged with two valve casings; the motion shaft or lever works between, and when only one valve casing is applied the motion is transmitted by a connecting rod to another motion shaft that gives the motion to the two valves of the same cylinder. The main and cut-off valves can be understood from the illustration. When compound cylinders are used, the high pressure steam is admitted first through the trunnion of the small cylinder, and after having acted in it passes through an exhaust passage into the large cylinder, and after doing duty there passes into the condenser.

Fig. 109.



Löbnitz's Arrangement of Main and Cut Valves, with Link Motion and Expansion Gear for working them, for Oscillating Marine Engines, patented in the year 1864.

The eccentric motion for the working of the cut-off valves is illustrated in detail by Fig. 110, on the next page, which is a section and end view of the variable cut-off eccentric attached to a long cylindrical boss sur-

rounding the shaft. In this boss is cut a slot, pa
the centre line of the shaft, in which slides the pin
the point of the pin is further let into an angulated
by moving the
drant, the clutc
move the pin, w
slot, and thus shi
eccentric to an
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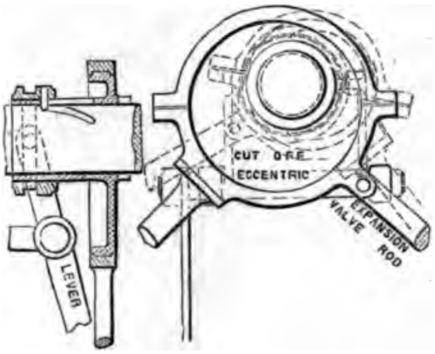
the engines are

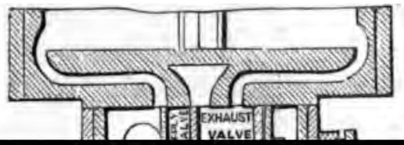
Fig. 110.



Löbnitz's Variable Eccentric Expansion Gear, adjusted by a Sliding Clutch and Lever, patented in the year 1864.

At the end c
Mr. King, an en
shire, with two
and Howell, pa
arranged valve a
they presumed, all the ends dependent for the perfec
Their contrivances partly consisted in the adoption
within the other, as illustrated by Fig. 111, which
a separate valve
tained in that fo
steam. The supp
the valve rod in
while the exhaust

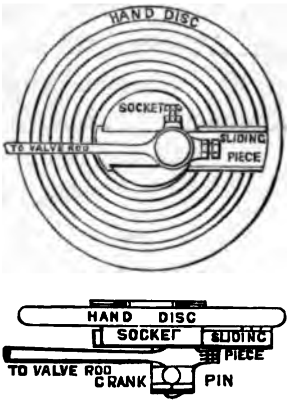
Fig. 111.



the exhaust port simultaneously therewith, and allowing it to remain open during the greater part of the stroke, although the steam may be cut off at a quarter or other fractional part of the stroke.

Mr. King's ideas of valve motion are illustrated by Fig. 112, which is an apparatus for varying or altering the position of the eccentric or crank pin by which the slide valve or valves are driven, and whereby the extent of motion is to be regulated, or the motion reversed. To effect this, the valve rod is driven from a crank pin, and this crank pin is fixed in a dovetailed sliding-piece, dovetailed into the socket that is fixed or formed on the crank shaft. This dovetailed socket is across, or nearly so, the axis of the shaft in which direction it slides; it has feathers or projections on the back part, which fit into a spiral groove cut in the hand disc, which is mounted loosely on the shaft. This disc, if not acted on by any separate means, rotates at the same velocity as the shaft, and the crank pin maintains the same radius. In the position shown the crank pin is at its extreme radius, giving the valve its greatest extent of motion, consequently admitting steam throughout the length of the stroke. If it is desired to give the valve less motion it is simply necessary to impart rotation by hand to the disc at a little quicker rate than the motion of the main shaft, which will cause the spiral groove to operate on the feathers and the sliding piece, and traverse it a greater or less distance in the radial direction. To reverse the engine it is simply necessary to traverse the sliding piece, so that the crank pin will pass across the axis to the opposite side of the shaft. To move the crank pin from a lesser to a greater radius it is simply necessary to retard the motion of the disc, and so allow the shaft to run a little quicker than the disc, the effect of the spiral groove being to traverse the piece as desired.

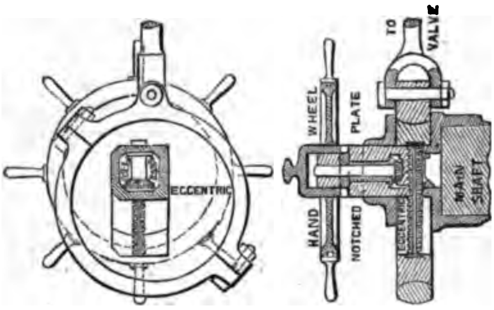
Fig. 112.



King's Spiral Grooved-Disc Valve-Motion, used as Expansion, Reversing, and Stopping Gear, patented in the year 1864.

But Mr. King and his colleagues even thus far had not expended their powers of invention, for they patented also a shifting eccentric motion, and gear attached, which ran away with Mr. Atherton's scheme, dated 1850, as illustrated on page 30 by Fig. 26. Certainly Mr. Atherton made that arrangement as simple as he could, whereas Mr. King and his party introduced bevel gearing; which, by the way, Mr. Atherton did also, to work the screw motion rod; instead of a rack as Mr. Atherton proposed in one case; and the illustration, Fig. 113, represents Mr. King's mode of carrying out the modification in this way.

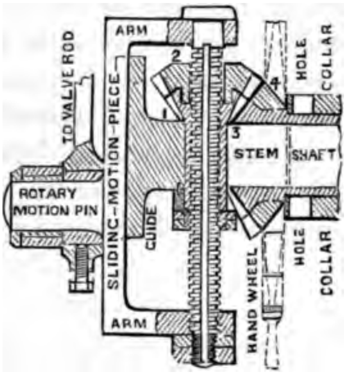
FIG. 113.



King's Bevel Gearing for shifting the Eccentric when used as Expansion Gear for a Range of Cut-offs, patented in the year 1864.

On the end of the main shaft a hollow casting is fixed, on the square part of which the eccentric is fitted, and furnished with the screw motion rod; on this screw rod is fitted the fixed wheels, one having a screwed boss fitting the other wheels, and connected by a feather and groove; a pinion gears with the wheel that carries on its shaft the hand wheel, while the other pinion gearing with the other wheel has fixed on it a notched plate, which may be fixed by a bolt fixed to a part of the framing, while the hand wheel may be fixed or loosened by a sliding motion piece, which has formed with it a pin and arms: the latter being in connection with the "screw motion rod," that adjusts the travel for the valve. This rod has fitted around it two bevil pinions, the smaller, 1, being as a nut on the rod and the larger, 2, being loose thereon, but has a feather in the boss which slides in the groove in the screw motion rod, causing it to rotate therewith; the pinion 1 revolves independently of pinion 2, and has a tube piece passing through the stem shaft, in which it is free to rotate. Bevil pinion 1 gears with another bevil pinion 3, that is fixed on a round part of the stem shaft, while pinion 2 gears with bevel pinion 4, that is, fitted loosely on the neck of the pinion 3; pinions 1 and 2 have an equal number of teeth, as also have pinions 3 and 4. In one piece with the largest pinion, or fixed thereto, is a hand wheel, as shown dotted: it is arranged that the hand wheel may either be held fast and prevented from rotating, or it may rotate freely with the main shaft; in either case no effect is produced on the sliding motion piece, for when the wheel is held fast, motion will be given to pinion 2 by gearing with pinion 4, as then the former pinion carries the screw around with it and the sliding piece revolves.

FIG. 114.



King's Bevil Gearing for regulating the Travel of the Slide Valve when worked by an adjustable Rotary Pin, patented in the year 1864.

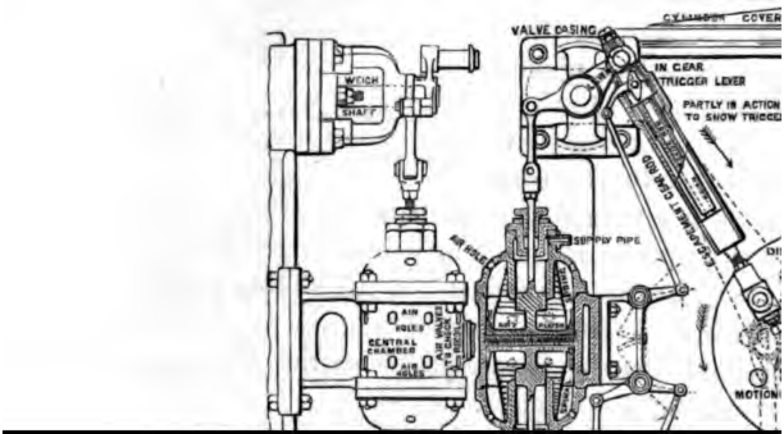
It was mentioned that pinion 4 is fitted loosely on the neck of pinion 3, but it is actually fixed to a collar on it, and when the hand wheel is fixed, the collar is also held fast, by slipping a bolt, mounted on the bearing or frame, into one of the holes shown. The rotation of pinion 1 with the shaft will produce a rotation on its own axis by reason of its gearing with pinion 4—which is locked as above mentioned—and will neutralise the effect of the rotation of the pinion 2 on the screw rod, which will therefore maintain the same relative position.

Supposing it is desired to vary the position of the screw rod, and with

it the crank pin, the hand wheel, and with it the
in the same or in an opposite direction to that of th
the pinion 2 will then receive a motion at a v
than the motion of pinion 1, which will result i
being imparted to the rod, and consequently a
motion pin to a position having greater or less
such as may be desired; the same action wil
traversing the pin across the guide in order to re

At the beginning of the year 1865, Mr. J. F.
his inventive powers to valve-gearing, but this t
appliance, as illustrated by Fig. 115, which is fro

Fig. 115.



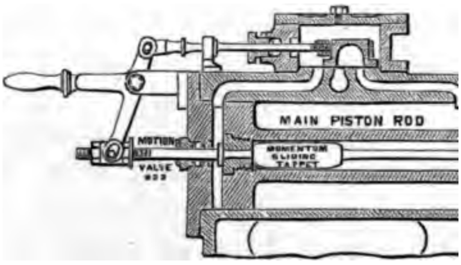
valve-gear; also is shown a portion of the valve casing in which may be one of the ordinary steam admission ports and a plain slide valve made to cover the ports with sufficient lap to prevent leakage and to suit the action of the valve. The port and slide faces may be flat or curved according to the plan adopted to move the valve; the slide valve is worked by drivers on a weigh shaft, passing through a stuffing box; this weigh shaft might give motion to any other kind of valve which requires little power to move it. But in the present illustration a valve commonly called the "Corliss" valve is supposed to be used; a rod worked by an eccentric or crank on the main crank shaft, or on a supplementary shaft, is driven by the crank shaft, and the reciprocating motion of this rod causes the disc plate to vibrate on a pin. On the disc plate are four pins, two of which only are shown, and one of these gives motion to the escapement gear rod, which is attached by a pin and lever to the weigh shaft, which imparts motion to the valve for admitting steam to the cylinder. The escapement gear rod consists of two principal and distinct parts, and one of which is always connected to the motion pin on the disc plate, and the other to the lever pin. There are two steel spring clips bolted to that part of the escapement rod which is attached to the disc pin, and these spring clips are connected to that part of the escapement rod which is attached to the lever pin by the grip of the projecting edges of the hardened steel tubing. The trigger lever, toe piece, or trigger works on a pin within the tube, and is connected by rods, &c. to an adjustable handle accessible to the engineer in charge. When the engine is started, and the escapement rod is in gear, as shown in the illustration, the motion of the disc plate and escapement rod, in the direction of the arrows, brings the trigger lever in contact with the insides of the spring clips, and throws them out of gear, and the admission valve is instantly closed by the action of a spring or weights acting on the top lever and weigh shaft; and the time that the clips are disengaged and the admission valve is closed, can be varied as required by the relative position of the trigger lever, which is held in any position at the discretion of the engineer in

charge by the rod, or the rod may be connected
regulates the speed of the engines by the amount
by the valves. The two parts of the escapemen
are shown in the illustration as guided in the sar
guide rod and bush.

The escapement gear rod is also shown diseng
clips being pressed outwards by the pressure of
therefore allowing the loose tubular parts of the
separated by the closing action of the slide valve.

It will doubtless be remembered that on page
Fig. 51 an arrangement of "self-acting valve-g
lated by steam, and we now illustrate another se
which depends *entirely* on the momentum of a sl
which of course "must never stick or hang fir
be fully appreciated, we illustrate it by Fig

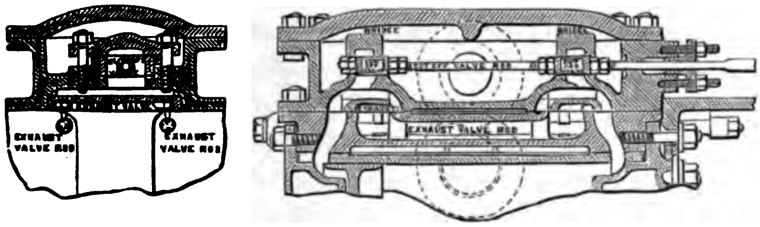
FIG. 116.



by which the valve may be moved when desired, and supposing the piston should be started from the position shown in the illustration and not arrive at the end of the stroke, the tappet would continue its motion and would reverse the position of the slide valve. If desired, the tappet and its rod which is in connection with the valve spindle may be wholly external of the engine and away from its piston rod, but suitably in connection or communication therewith, so that it may have a capability of movement, and continuing its action on the valve after the piston has ceased to act. But it is not essential that the tappet or instrument acting on the valve of the engine should slide on a bar; on the contrary, a tappet or instrument on an axis put in motion by the piston of an engine, and acting on the valve of the engine, may be used, such tappet or instrument being arranged to continue its rotation by momentum after the piston has stopped.

We now advance to the year 1866, and notice next that Mr. Porter received a communication from Mr. Allen, who patented the arrangement of valves and gear as illustrated by Fig. 52 on page 59, and preferred after to use them as shown in two sectional elevations by Fig. 117.

FIG. 117.



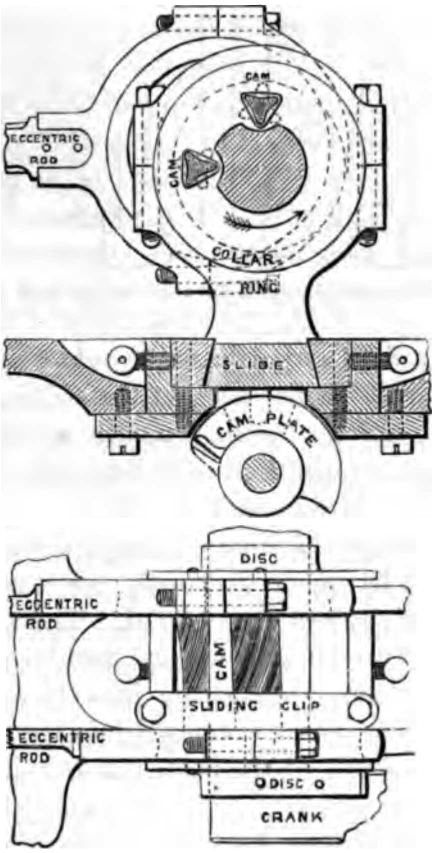
Allen's Equilibrium Cut-off and Exhaustion Valves for regulating the Steam to and from the Cylinder of an Engine, patented in the year 1866.

The supply ports are formed in the port face, and communicate with each end of the cylinder in the usual manner, as shown. The cut-off valves, which are fitted to slide on the port faces serve only for admitting and cutting off the steam, the additional or exhaust valves being provided to control the escape or exhaust of the same. These valves slide upon the facing over the exhaust ports, and are so arranged and operated as to close the latter when the communication between the corresponding end of the cylinder and the steam chest is open. The other valves are each constructed in the form of an oblong frame whose surfaces are parallel; the lower surface is fitted to slide upon the port face, while the upper surface works in contact with the under surface of the plates or bridges which prevent the pressure of the steam on the back of the valves. Each of the latter is constructed with a boss, through which the rods pass, the said rods being secured therein by the adjusting nuts. These valves are operated by their rod, while the exhaust valves are operated by the lower rods; all of the said rods being connected to separate levers on the rocking shaft or other convenient working part of the engine. The left-hand cut-off valve is shown opening the port, while the right-hand valve is moving towards the forward end of the cylinder, and keeping closed the apertures, which all communicate with the other port, that admits the steam into the cylinder at that end. These apertures, which equal the effective area of the said port, increase in width as the valve moves forward till the edge of the valve reaches the middle of the port, at which point the areas of all of those apertures are equal to the port.

In the same year, 1866, a Mr. Chapman of Lincoln proposed to substitute for the link motion his arrangement of eccentric-gear, as illustrated by Fig. 118, in the following manner:—

To the inner side of each crank is bolted or otherwise fixed a circular it is evident that as it is moved from one to the other the action of the sides of the openings against the cams will impart a partial revolving motion to the latter, and hence the position of the eccentrics with regard to the cranks will be reversed, and consequently the crank shaft would be caused to revolve in the opposite direction to the arrow. It will also be evident that the eccentrics can be caused to assume any intermediate position, and therefore to give any required amount of expansion by moving the clip a portion of the distance only. The cause of the sliding of the clip on the crank shaft is shown in the elevation, which is by a ring embracing the collar that is connected to a slide piece working in a groove in the bed plate. From the under side of the slide projects a pin which fits in a groove in the twisted cam-plate keyed upon a transverse shaft, upon one end of which is also keyed a lever connected to another lever by a link: this lever is provided with a bolt working in notches of a quadrant, and by means of this lever the position of the eccentrics and consequently the direction in which the engine revolves—and the amount of expansion at which the steam is worked—are controlled.

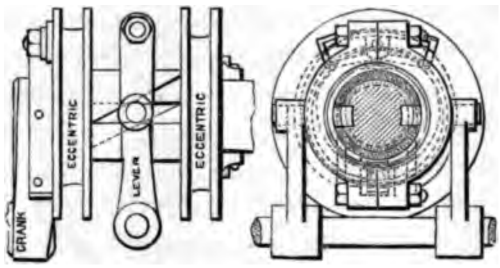
Fig. 118.



Chapman's Adjustable Eccentric Gear, proposed as a Substitute for the Link-Motion, patented in the year 1866.

Mr. Chapman proposed also a modification of his first arrangement for shifting or sliding the clip by direct levers, as shown by Fig. 119 on the next page. In this modification each eccentric band is situated also between two discs. The outer discs, which are bolted to the cranks, are provided with slightly curved horizontal slots, so arranged that a constant lead is maintained, and the inner discs with radial slots. The pin which supports the eccentric band passes through the slides, which work in these slots. The eccentric band is also provided with a guide pin, which works in a similar slide moving in a radial slot in the disc. This modification may also be used as a fixed eccentric to be set at any degree of expansion, and fastened with the nut without the shifting gear.

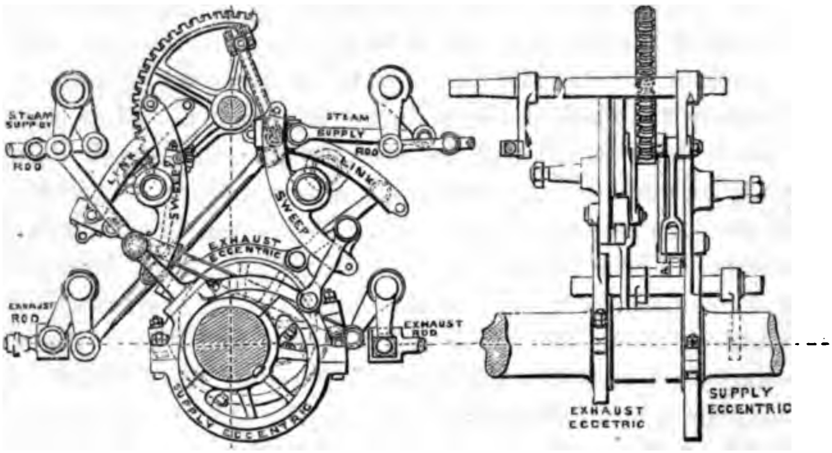
Fig. 119.



Chapman's Adjustable Eccentric Gear, proposed as a Substitute for the Link-Motion, patented in the year 1866.

In the smiling month of May, 1867, Mr. Henry Turner patented an arrangement of link-motion valve-gear, which must have cost him a deal of time, and no end of trouble, to have conceived; and the birth of it must have been a happy deliverance for him. But to enable the gear to be appreciated justly, we must first inform our readers to what class of engines it was fitted. The arrangement consisted of four cylinders, two high pressure and two low pressure; the high-pressure cylinders exhaust their steam into the low-pressure cylinders, and the steam is from thence exhausted into the condensers. Two cylinders are fixed on one side of the main cranked shaft, namely, one high pressure and one a communication across in the shortest direction with both ends of the low-pressure cylinders, so as to bring the waste of steam in the passages to the smallest limit. To effect this purpose the two cylinders, high and low pressure, working in conjunction, must have their respective pistons working in opposite directions at the same period. In these engines the above-named object is obtained by fixing firmly in the forward frame of the engines, that is to say the frame farthest removed from the work or resistance which has to be overcome by power, and on the centre of the circle of the main engine shaft, a stud or pivot on which a crank lever is allowed to work freely; this crank does not transmit any power from the engines, but acts only as a radius guide or link to the forward engine crank pin. The forward cylinder is made high pressure in these engines for convenience, but could be made low pressure if required. One end of the radius guide shaft works freely on the stud or axle; the other and opposite end has a crank pin fitted or forged on, to which the connecting rod of the forward engine gives a circular motion around the axis of the shaft: one end of this crank pin is attached to the crank lever; the other end has a circular piece forged on it, forming a bearing for a connecting link or rod which is made of a sufficient length to form a communication at the opposite end with another crank pin on which the connecting rod of the cylinder opposite works, and which cylinder is fixed on the other side of the engine main shaft. The slide valve-gear, as shown in two views by Fig. 120 on the next page, is arranged in the following manner:—Two eccentrics are keyed or otherwise fixed to the engine axle or shaft. One of these eccentrics works two supply steam valves, and the other one works two exhaust valves; these exhaust valves form the outlet from the high-pressure cylinders and the inlet into the low-pressure cylinders, and also the exhaust from the low-pressure cylinders into the condensers. Two rods are attached to each eccentric band; one rod is firmly fixed or bolted to the band, the other rod has a jointed end which works loosely on a pin. The foot of the first-named rod and the boss for the pin on which the second rod works are ninety degrees asunder. Each of these rods works a lever, to which lever is attached a sweep, the radius of which is pointing towards the slide valve instead of towards the engine shaft as is usual in the ordinary link motion. Each sweep is provided with a sliding block, which is raised and lowered above or below the pivot, on which the sweep works, imparting a forward or backward motion to the above-named connecting rod, according to which side of the pivot the sliding block is situated at the time. These rods are connected at one end to the sliding blocks, the other end to the levers giving motion to the

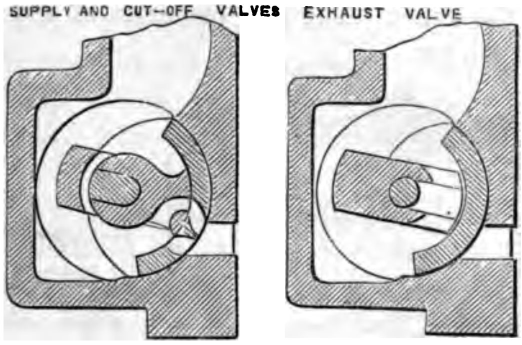
FIG. 120.



Turner's Link-Motion and Valve Gear, for high and low pressure combined, Marine Screw Engines, patented in the year 1867, and fitted to the engines put in the Greek Gunboat "King George," by the Thames Iron Works Company.

Our next example of valves to be noticed is of the "Corliss" class, being something similar to those illustrated by Fig. 48 on page 54. Mr. Wood, of Bolton, patented these valves, as shown by Fig. 121, and he also patented their arrangement and gear as shown in three views by Figs. 122 and 123 on the next page.

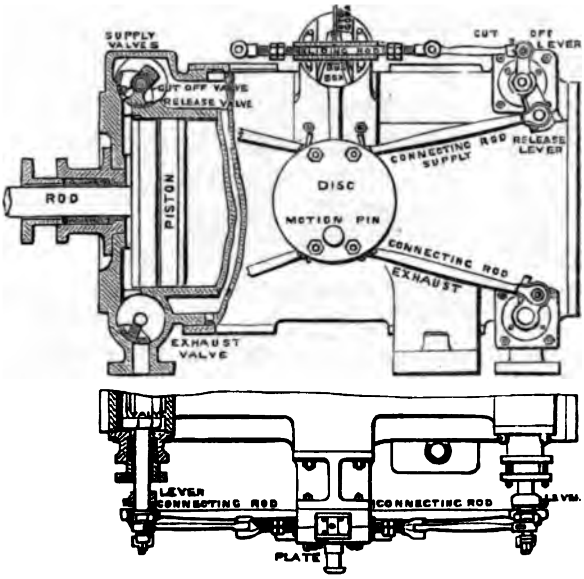
Fig. 121.



Wood's "Co liss" Valves, for Admission, Cut-off, and Exhaustion, separately, patented in the year 1867.

The supply and release seating valve, consists of a segment of a hollow cylinder, having a reciprocating or oscillatory motion from its rod, and is made long enough to fill the steam chamber. In the face of the said valve and through it are two lines of passages or openings cut in the direction of the rod of the valve, having the same breadth of opening in the outer circumference of the valve as in the steam port of the cylinder, and on the inner circumference the division is widened to the extent of the cover or lap; so that the cut-off valve when so placed that the aperture or opening is exactly over the division betwixt the passages, will have sufficient lap to be steam-tight; also this valve or movable seating has pieces cast on each end forming the sector of a circle, which pieces are cut out in the direction of its radius to the diameter of the spindle. The ends of the pieces are accurately fitted on to projecting arms, as shown in the elevation, formed on the hollow spindle, so that any motion communicated to the said hollow spindle may be transmitted to this valve. This same hollow spindle is so constructed that a part of it in the direction of equal in length to the boss of the cut-off valve, w space so cut out, and the two ends of the said hollo gether by a bar or bridge at a sufficient distanc clear the boss of the valve. The extreme ends c

Fig. 122.



Wood's "Corliss" Valves and Gear, in elevation and plan, being, three distinct Valves at each end of the Cylinder for "Admission, Cut-off, and Exhaustion," with the Corresponding Gear, all under the control of the Engine Governor, patented in the year 1867.

Wood's '
Section
view t
the ye

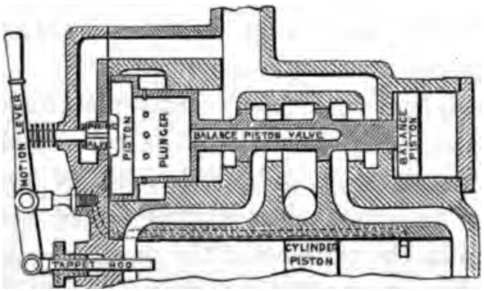
latory motion for a certain limit like the other valve, on the back of which it may be retained or kept in position either by steam pressure or by springs. The boss of the cut-off valve is made with an oblong hole through it so as to allow for wear on the face thereof, and fitted into this hole is a fast key or feather having a corresponding groove cut in the spindle, into which the fast key or feather is made to fit easily; the motion, therefore, of this valve is communicated to the spindle which works inside the outer hollow spindle, and through which it protrudes and terminates; in or affixed to it is an arm or lever which is connected to a sliding rod by a connecting rod. This rod works in two bushes placed in a cylindrical box, in such manner that they have a limited motion in the direction of the sliding rod. These bushes are cylindrical at their outer ends, and have a square section at their other parts. In the ends are grooves cut at an angle to suit angular guides formed on plates which are placed on either side of, and have a motion at right angles to that of the bushes. The plates work in a chamber or cell in the cylindrical box, the said plates being fastened together and connected by a rod to the governor, so that any variation thereof will give motion to the plates up or down, and thereby cause the bushes to move either outwardly or inwardly, as the case may be; the said bushes coming in contact with the adjustable stops or nuts on the rod either at an earlier or later point of the stroke, thereby arrest the motion of the cut-off-valve on the back of the release valve, and consequently cutting off the steam at an earlier or later portion of the stroke, according as the varying engine load to be overcome may determine.

The exhaust valves are worked in the same manner as the top valves, and are fitted to arms or levers on a spindle by the same method, and also derive their motion from the same disc.

In the same year Mr. Wood invented the steam "dash-pot" as illustrated by Fig. 124 on the next page, which represents a vertical section of an arrangement of steam piston and cylinder to be employed for closing the valve when released from the eccentric rod's motion, and the adaptation of a steam buffer to prevent concussion on the closing of such valve.

the governor, according to the position into which the notch is brought to come into contact with the projection, which in its descent forces down the lever, and opens, through the medium of rods connected to the valve spindle, the "gridiron" slide valve a certain distance for admitting steam, which is regulated according to the duration of contact between the bent inclined surface and the adjustable pin, that is determined by the governor. When the eccentric rod is unhooked, the steam piston in connection with the lever closes the valve as described, the levers and rods in connection with the valve spindle remain disconnected, and in disuse until again caught, during the descent of the eccentric rod, at which time the valve is again opened.

Fig. 127.

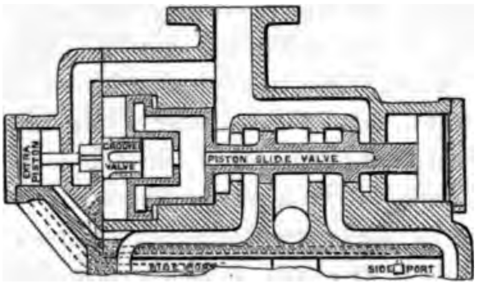


Brown's Self-Acting, Balance Piston, Valve Gear (regulated by a Spring and Tappet rod), patented in the year 1868.

On page 58 there is an illustration shown by Fig. 51 of an arrangement of steam self-acting valve-gear, patented in the year 1862, and on page 132 by Fig. 116, another arrangement for the same purpose is shown; and again we show by Fig. 127 a third proposal by Mr. Brown of Surrey, which he patented in the year 1868; his idea was to make a balance piston valve to perform the regulation of the admission, cut-off, expansion, and exhaustion of the steam, and to cause the steam to actuate the valve, or similar as that done steam port and the outer port at the opposite end of the cylindrical seat, thus leaving this end of the seat, and consequently the outer port formed therein, open to the valve casing, by which the valve seat is surrounded; this casing is connected with the exhaust, and is conveniently cast in one piece with the cylinder of the engine. At one end of the valve's hollow piston rod, is formed a hollow plunger which works in a cylinder formed at one end of the valve casing; the left hand end of this cylinder is closed by a cover which is formed in one piece with the end cover of the cylinder of the engine; the back end of the plunger carries a piston which is of a larger diameter than the other, and works in a corresponding enlargement in the valve cylinder. A constant supply of steam, is admitted to this enlarged part of the cylinder, to act against so much of the piston as projects beyond the plunger; this is effected by admitting steam through the hollow piston rod by small holes, and allowing the steam to pass therefrom through other holes formed through the plunger. The pressure of steam thus acting against the outer ring of the piston will tend to press the piston back against the back end of the cylinder, and so hold the valve over to that end of its stroke, as shown in the illustration. Through the cover of the valve cylinder is a passage leading to the port in the side of the cylinder near its other end. Through this cover is also another passage leading to the exhaust: this passage is fitted with a valve formed with a rod which passes out through a stuffing box in the end cover; this rod is acted on by a spring which holds the valve closed. A tappet rod passes through a stuffing box in the end cover of the engine cylinder; the outer end of this tappet is jointed to the lower end of a lever; the upper arm of this lever bears against the rod of the valve so that when the engine piston at the end of its stroke comes against the tappet the lever may be pressed back and so caused to open the spring valve.

Figure 128, on the next page, shows a longitudinal section of part of an engine similar to that shown by Figure 127, except that the spring valve is opened and closed by a small piston instead of by the tappet rod, and that the small flow of steam is governed by a grooved valve projecting out

Fig. 128.



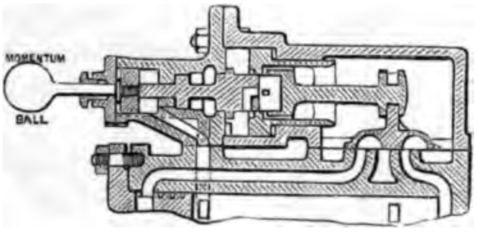
Brown's Self-acting Balance Piston Valve Gear, without the Steel Spring and Tappet Rod, as shown in Fig. 127; patented in the year 1868.

from the smaller valve. In this arrangement the
works in a short cylinder, the inner end of which
to the port
end of the e
outer end of
also by a pa
the port in
cylinder.
when the en
towards the
has passed
then steam
port to the b
and will so open the small valve, thus at once cau
be shifted; steam will also immediately pass throu
whilst that side port will be opened to the exhaus
valve will be closed. As soon as the engine pi
again over this side port, steam will be acti
of the extra piston, and the small valve will b
pressure of steam acting upon the top of the
engine piston has travelled back to the opposit
cylinder and has passed over the other side port,
described pass through this port, and will act a

valve will be held closed by the pressure of steam upon it, while the valve will be thus held closed until the engine piston has passed beyond the side port, when the same operation will be repeated.

The illustration shown by Fig. 129, is another arrangement by Mr. Brown in which a slide valve is used to govern the steam and a balanced piston valve is used to work the former; in fact two duties in the place of one as before.

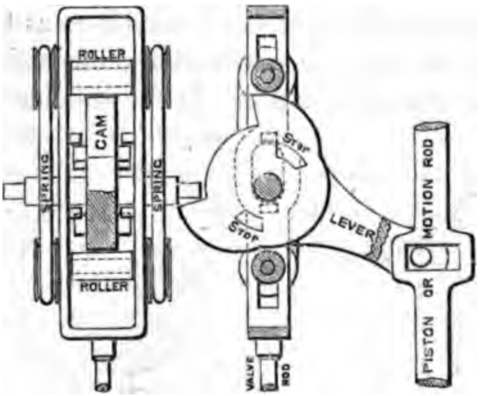
FIG. 129.



Brown's Steam Balance Piston Valve, for working a double-ported Slide Valve; patented in the year 1868.

Just immediately after Mr. Brown brought out his ideas of what valve gear should be, a Mr. Pocock of London brought out his also, as shown by Fig. 130, which is a lever and a cam, worked by the main piston-rod or by any other means; the cam is fixed on a pin that is supported in two slots in the side frames, connected to the valve on each side of the cam: and india-rubber springs keep the top and bottom rollers in the frames, always against the cam, so that by the peculiar form of the cam an unequal motion is imparted to the valve-rod; two stop-lugs on the cam and side frames also regulate the action of the springs.

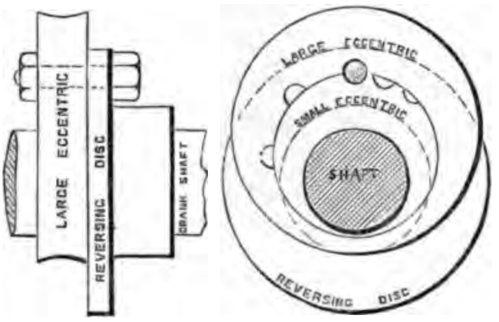
FIG. 130.



Pocock's Lever, Cam, and Spring Valve Gear; patented in the year 1868.

To try to supersede Chapman's ideas for shifting the eccentric, as shown by Fig. 119, on page 136, a Mr. Tasker of Andover patented a method as shown by Fig. 131, on the next page, which is side and elevations of the arrangement of two eccentrics of unequal diameters, the smaller being contained in the larger. These eccentrics are of course loose on the crank shaft, on which is keyed a reversing disc or plate by which the eccentrics are maintained in their adjusted position, as required when fixed by means of a bolt and nut as shown. The mode preferred to adopt for altering and adjusting the eccentrics is as follows:—At various distances on the outer edge of the smaller eccentric several semicircular or other shaped notches are cut, the said distances being determined according as it is required to cut off the steam or to close the port at $\frac{1}{4}$, $\frac{1}{3}$, $\frac{1}{2}$, or any other part of the stroke. On the inner edge of the larger eccentric other correspondingly shaped notches are made at various distances according to the relative size of the two eccentrics. The bore of the larger eccentric is such that the smaller fits it so as to enable the two to be turned on or around the crank shaft independently of each other. In adjusting the eccentric a notch in the smaller one is turned opposite to the corresponding notch in the larger eccentric, and the two eccentrics are held together by the bolt passing through them both and

FIG. 131.



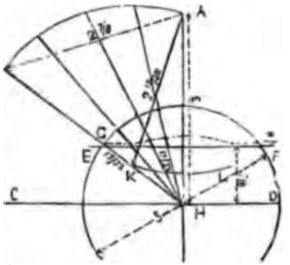
Tasker's Adjustable Eccentrics, for altering the travel of the Slide Valve; to be used as an Expansion Gear; patented in the year 1868.

FIG. 132.

we find them. This illustration is shown in side sectional and complete end elevations, the reversing disc or plate is here keyed on the shaft as in Fig. 131, and the eccentric is secured to the disc or plate by a bolt and nut as in that case; the eccentric is shown as in mid-gear, but it can be secured in full or any other gear as required by slackening the nut, then turn the eccentric around on the plate, and tighten the nut, so as to hold the eccentric in the settled position, the eccentric in this case is slotted in its bearing on the shaft, thus dispensing with the inner eccentric shown in Fig. 131.

The illustration Fig. 133, is a geometrical diagram of the action of the eccentric shown by Fig. 132, also for determining the radius of the curved slot in the eccentric.

FIG. 133.



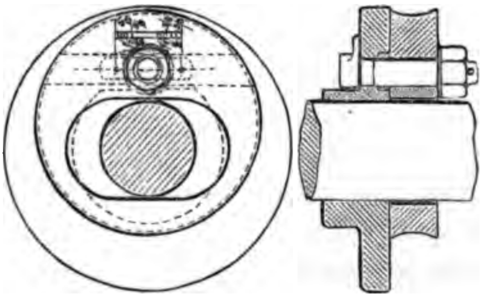
Geometrical diagram of the Adjustable Eccentric shown by Fig. 132.

In this case the lap of the valve is $\frac{7}{8}''$, lead in full gear $\frac{1}{16}''$, travel three inches. The radius of the slot $2\frac{17}{32}''$, and its distance $\frac{17}{32}''$ from the centre of the eccentric, were found from practice. The construction of the diagram will be understood by observing that the centre from which is described the curved slot, must always be on the same radial line through the centre H as the centre of the eccentric. It must also be in this case $\frac{17}{32}''$ from the centre of the eccentric and $2\frac{17}{32}''$ from the centre of the bolt. A H, C D are centre lines. C is the centre of the eccentric in full gear. K L is a radius described from the centre A of the bolt. K G is found to measure $\frac{17}{32}''$; and by measuring $\frac{17}{32}''$ from the arc K L along other radial lines, as shown, other positions for the centres of the eccentric will be formed, and their distance from the line E F will be the lead of the valve for those positions of the eccentric. The lead may be made to increase or diminish as the eccentric approaches mid-gear by reducing or increasing the radius A K.

Another arrangement of adjustable eccentric by Mr. Hartnell is shown on the next page, by Fig. 134, in sectional and complete elevations. In this case the adjustment is effected by *sliding* the eccentric on the shaft instead of turning it partly around, but excepting that, all the details are much as those just described and illustrated.

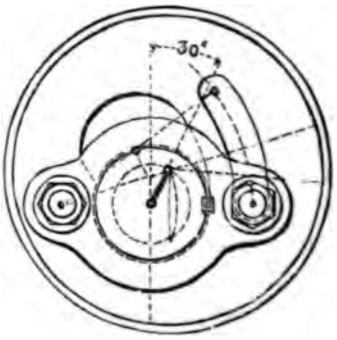
A different method of connection is shown by Fig. 135. This has two bolts and nuts for the adjustment of the eccentric, and the securing disc is of the smallest proportions coincident with strength of material. This has been used in America for several years lately with as much success as any other arrangement of a similar order. Analogous with it is this shown on the next page, by Fig. 136, which although of a slightly different proportion and shape, is practically similar in its workings.

FIG. 134.



Hartnell's Adjustable Eccentric, with a straight Slot for the bolt, for altering the travel of the Slide Valve; to be used as an Expansion Gear; patented in the year 1868.

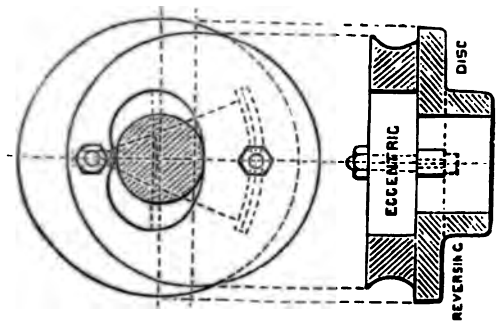
FIG. 135.



Adjustable Eccentric, with curved Slots in the Eccentric, for altering the travel of the Valve; secured with two bolts and nuts; used as an Expansion Gear in the year 1868, and for six years previously.

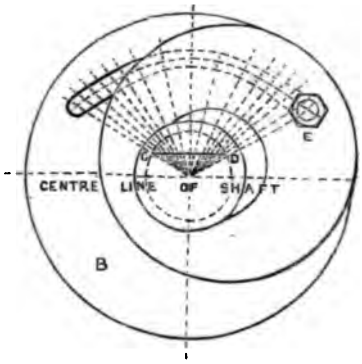
the slot required in the disc; also it must be understood that, the limit of the distance D E is proportionate to the alterations of the grades of expansion required.

FIG. 136.



Messrs. Ruston, Procter and Co.'s Adjustable Eccentric, secured by two bolts and nuts, for regulating the Cut-off of the Steam by the Slide Valve; as used in the year 1868, and also in 1867.

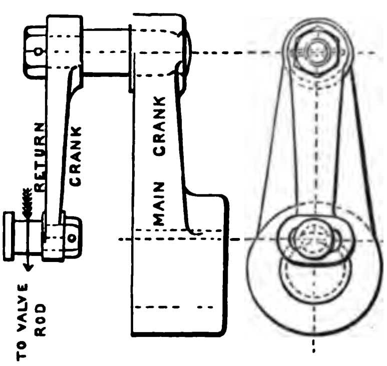
FIG. 137.



Robey's Adjustable Eccentric, with an irregular curve for the bolt, for the regulation of the Cut-off of the Steam by altering the travel of the Slide Valve; as used in the year 1868, and for two years previously.

Of course it is known that the centre of the eccentric revolves around the centre of the shaft when in motion, or as a crank pin: and equally of course a small crank keyed on the main crank pin, and turned towards the centre of the shaft less the half travel of the valve, with a pin in it, will perform all that an eccentric can do; this can be better understood from the illustration Fig. 138, which is side and end elevations of the main and return cranks of an engine without any eccentric; the length of the return crank is less than that of the main crank by the half travel of the valve—or "throw" of the eccentric if it were used—but the same result would be effected if the return crank were longer than the main crank as much as it is now shorter, or the motion pin below the centre of the shaft instead

FIG. 138.



Ordinary Crank-Motion for working the Slide Valve of an Engine; most often used for Donkey Pump Engines during the last fifteen years.

of above it as shown. The slot in the end of the return crank is for the alteration of the grade of expansion or point of cut-off by the slide valve. It is obvious also that this slot can be curved to suit any requisition of working, or indeed of any shape as may be desired.

We have from page 148 illustrated and explained six differently arranged adjustable eccentrics, and as they all are said, by the inventors, to be perfect, or at least nearly so, we have a very conclusive evidence of what differences of opinions lead to, inasmuch that in no two instances are the principles or the practice the same, and yet each maker or inventor claims his as the best.

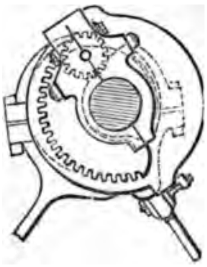
Now if shifting the eccentric around on the shaft is all that is required for expansion gear, how much better must the arrangement be that shifts the eccentric while it is in motion to the greatest exactitude due to the speed of the piston, instead of stopping the engine to re-adjust the eccentric when desired; constant lead being of course not deemed essential in the first case, but rather a lead proportionate to the speed. It must be remembered also that there is a vast difference in the result according as the eccentric is shifted, that is, whether at right angles in a straight line, or in an eccentric curve, or radially.

FIG. 139.

Mr. Atherton knew something of that circumstance when he patented his adjustable eccentrics in the year 1850, as illustrated on pages 30 and 31, and Messrs. Randolph and Elder, the eccentric, and situated between the teeth and those on the loose wheel; this pinion therefore will shift the eccentric either to the right or left when the brake is tightened, and thus alter the grade of expansion, and also reverse or stop the engines as required.

In the case of compound engines there would be two arrangements—that just described being for the high-pressure cylinder—and this shown by Fig. 140, being for the low pressure: it may be stated also, that the former has a short arc or a quadrant throw, while the latter has a half circle or a semicircular throw, due of course to the laps of the two valves, the respective pinions being made to correspond.

FIG. 140.

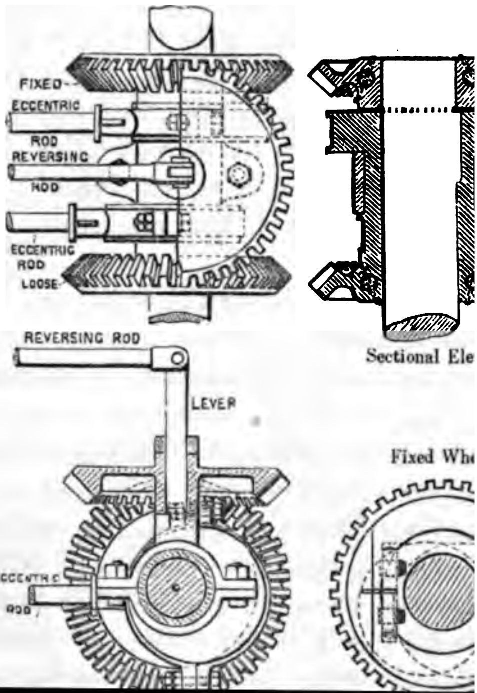


Randolph's Adjustable Eccentric, for Low-pressure Cylinders; patented in the year 1856.

A very ingenious method for shifting the eccentric while the engine is in motion also, is shown by Fig. 141, on the next page; this was invented by Messrs. Bruckshaw and Cornes of London, in the year 1867, and illustrates what means were resorted to, to make an expansion and revolving gear different from any other if possible. Spur gearing it will be remembered has been much used, and screws and nuts, and bevel gearing also; but mitre gearing has not been so often applied. The arrangement of this gear is as follows:—A mitre wheel is fixed or keyed on the crank shaft, opposite to which is another wheel loose on the shaft; this wheel has formed with it a tube, together with the eccentric or eccentrics; between them is a loose collar in halves connected together by bolts and nuts, on the upper half is a boss into which a lever is attached, and on the lever is keyed a third mitre wheel—shown in section in the end view and half only in the plan—that gears with the other wheels. Now obviously when the shaft is revolving the fixed wheel will, by the intermediated wheel, drive around the loose wheel, the tube, and likewise the eccentrics; but if the lever is moved to cause an exceptional motion to the loose wheel, then the eccentrics are shifted independently of the shaft, and thus the slide valves are similarly affected. When the lever is in the position shown, the engine is stopped, and

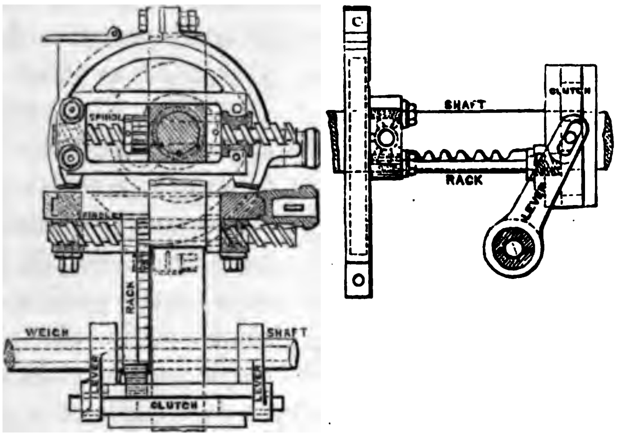
when on either of the extreme angular positions i
or the other; the plan and section shows two ec
used for two engines, or for two valves of o
required.

FIG. 141.



It will be seen by the end view that the crank shaft is made of square section at the part where the eccentric is, and that the long slot in the eccentric is fitted to this square portion so that it can slide across the shaft from the position of full gear forward to that of full gear backward, or remain in any intervening position, so as to vary the cut-off by shortening the length of the stroke of the slide valve. The traversing motion is effected as follows:—Through the square part of the crank shaft a screwed spindle is carried that is free to rotate and works in two brass nuts, fixed one at each end of the eccentric slot so that as the spindle rotates the eccentric traverses. A pinion is fixed on the screwed spindle close to the shaft which gears into a rack connected to a sliding collar on the shaft, and is moved along it by a pair of arms or levers fixed on a weigh shaft to which a hand lever is attached. It will be understood then, that when the rack is moved in a direction parallel with the crank shaft, rotatory motion is given through the pinion to the screwed spindle, and thus the required traverse of the eccentric is accomplished.

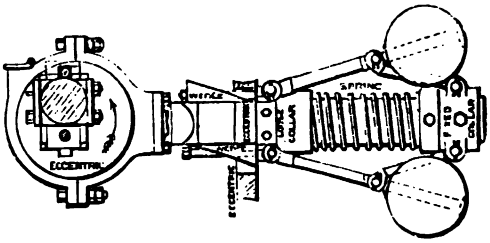
FIG. 142.



Turner's Adjustable Eccentric, worked by a Screw, Rack, and Pinion, with Levers and Clutch; applied in the year 1868.

To the present it will be remembered that all the adjustable eccentrics we have illustrated are either shifted by hand power when stationary, or by gear when in motion; but in both cases actuated by the hand as a separate means from the motion of the engine; Messrs. Robey of Lincoln, however, have dismissed the hand as a motive power, and by a ball governor, horizontally situated, actuate the eccentric with a combination of Dodd's Wedge Motion—which was invented as far back as the year 1839, as illustrated on page 17.—The illustration Fig. 143 shows the application of this gear to an engine with one slide valve. The eccentric is formed with a rectangular opening in it, which fits on a square portion on the crank shaft—as in the preceding example;—it is retained in any position at right angles to the crank, by two wedges of a parallel form which traverse forward and backward on the shaft within the eccentric, and thus its throw is altered. The mechanical arrangement is thus:—On the right hand of the governor there is a collar that is fixed on the shaft, opposite to which is a loose collar that is connected to the wedges. Obviously then, when the balls of the governor recede by their centrifugal action, the wedges are pulled by the rods through the eccentric, and it slides upward, or in the direction of the arrow in the end view; thus the travel of the valve is likewise

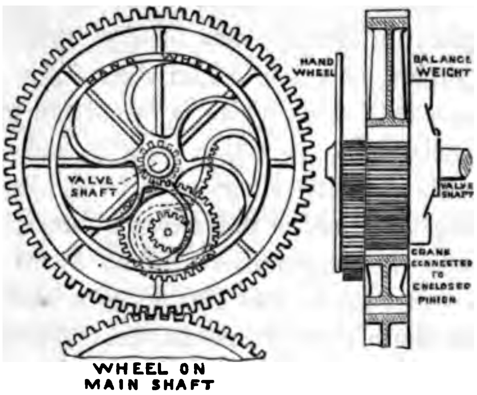
FIG. 143.



Robey's Adjustable Eccentric, worked by a Ball Governor and "Dodd's Wedge Motion;" applied in the year 1868.

been deemed imperative. Our French neighbours, however, have thought fit to copy Messrs. Maudslay's method to the extent of the use of cranks in the place of the eccentrics, when the slide valves are on the top of the cylinders and the motion shaft in front opposite the valve casings. The English firm, it will be remembered, use spur gearing also for the valve motion, as illustrated by Fig. 80 on page 99, and the cranks and shaft of course being formed together, are similarly shifted. The French valve gear is shown by Fig. 144, and its explanation is best expressed by our critique of the French Exhibition in the "Engineer" of August 23rd, 1867, thus:—"The valve shaft is driven by a pair of spur wheels of equal diameter, one being on that shaft, and the other on the main shaft, at the forward ends. Reversing, stopping, and starting are effected by tooth gearing on the end of the valve shaft; outside the spur wheel is a pinion, and beyond this a hand wheel with a rim, with a 'jam wheel;' in the body of the spur wheel is a space and a quadrant rack, the radii of which are taken from the centre of the shaft; in gear with the rack is a pinion, and on its shaft is a second pinion of a larger diameter than the first, which gears with the pinion on the valve shaft. Now on motion being given to the hand wheel, independently of the engines, the valve shaft will be turned around independently also, and thus the valves are stopped or shifted either way as required, but with the consequence that if the hand wheel cannot be instantaneously released by the 'jam-wheel' outside it, the engineer will be hurled away from his duty by the centrifugal force of the rim."

Fig. 144.



French "Whirligig" Valve Gear, of the Marine Engines that gained the prize at the French Exhibition of 1867.

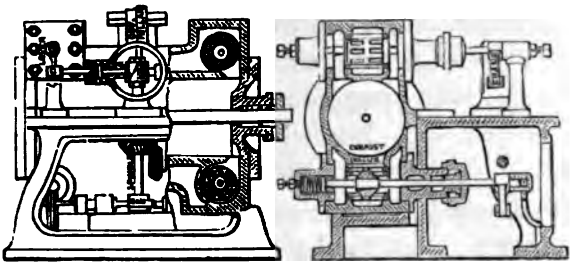
A very singular example of valves and gearing was patented in this

year, 1868, by Mr. Newton of London, for a
York, which consisted of the adoption of hollow
conical valves fitted into perforated shells that ar
chest. The valves are oscillated by means of
spindle of the governor, and when so moved, the
line with those of the hollow seats, and thus le
cylinder. When the projecting part of the cam
valve connections the valves will be closed.
arrangement of this cam and gear for operating t
chest is that the cam is of cylindrical or conical
jection, and is fitted on the spindle to be adjustal
movable stem, which is raised and lowered by the
balls. Levers which are attached to cranks proj
rods are with their ends held against the peri
when the spiral projection is brought between th
cam they are pushed off so as to open the val
equivalent devices throw them back again to clo
as the projection has passed. The projection of
on one edge and not on the other is consequen
than on the other; the opening of the valves is t
the height of the governor stem, and also by
around the governor spindle.

This arrangement was of course patented to elude
ment, and to show how it was accomplished we hav

end of the crank is fixed a bar which is by means of a spring held with its end against the cam or cylinder, as shown in the side elevation. As the spindle is being revolved the cam is once during every revolution brought between the end of each lever and the ring, and pushes the crank away so as to turn the valve in its seat, thereby opening the port. When the lever is not held out by the cam, the ports are closed. Now it is evident that the lower the cam is situated the longer will the ports remain open during one revolution of the governor, and the higher it is the quicker will they be closed, owing to the tapering form of the cam. If the engine goes too fast the balls will spread and raise the cam, causing less steam to enter the cylinder until the required equilibrium has again been obtained. The supply valve can be ground into the seat; one end of its shaft rests against a spring to allow expansion and contraction of the parts. Valves of similar construction are also used for the exhaust. They are there confined within seats as shown, and are operated by means of a full stroke cam mounted on the rotary spindle.

FIG. 145.

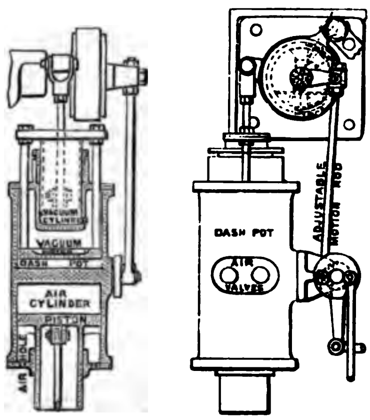


Loomis' Oscillating Cylindrical Perforated Valves, worked by Mitre Gearing, Levers, Cams, and Springs, controlled by a suitable Ball Governor; patented in the year 1868.

Early in this year Mr. Spencer came forward again with his notions of improved "Corliss" valve gear, in connection with a new "dash-pot," which had no springs, but solely depended on the atmospheric pressure and its exhaustion, or a vacuum, for the sudden motion of the pistons connected to the steam valves, as shown in sectional and

complete elevations by Fig. 146, and the advan
apparatus is cheaper than his other and equally

FIG. 146.



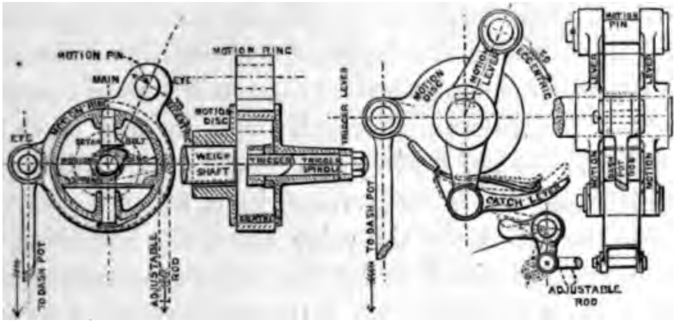
Spencer's Vacuum "Dash-pot" and Gear, for closing "Corliss" or other Equilibrium Valves; patented in the year 1868.

The arrangemen
and pistons work
cylinders, the effec
the closing of the
suitable gear, by m
ing air-tight in a
to a lever on the st
lever on a weigh s
to the steam valve
is drawn out by th
port, and thus for
on the inner side
the pressure of th
outside of the pist
port when the det
By this arrangement the movement required t
also gives motion to the vacuum piston and cr
the usual dash pot or air cushion can be formed
itself or by a separate cylinder and piston as pre

Inlet and outlet air valves are fitted to th
regulate the amount of vacuum required, and in

and thus releases the motion disc, also thereby permits it and the valve to be actuated by the dash-pot piston and rods.

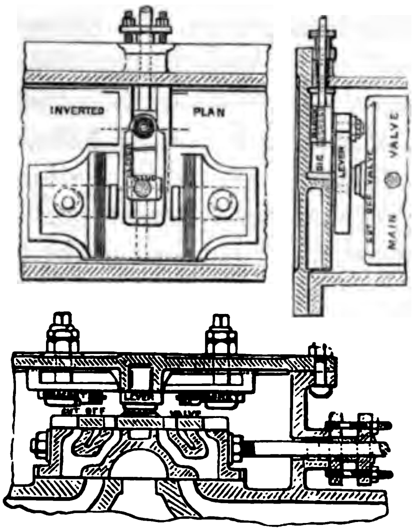
Fig. 147.



Spencer's "Radial Escapement Gear," for working "Corliss" and Equilibrium Valves, patented in the year 1868.

The second arrangement of gear is shown in two complete views on the right hand, in which levers and a spring perform the requisitions of the detent-bolt trigger and ring.

Fig. 148.

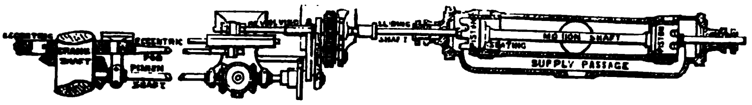


Shelmerdine's Main and Cut-off Valves, worked and regulated by an Eccentric and Ball Governor, patented in the year 1868.

Within one month after Mr. Spencer had petitioned for his patent just described, Mr. Shelmerdine, with two friends of his, the trio being at Manchester, began to patent the arrangement of valves as shown by Fig. 148, which is an arrangement of main and cut-off valves regulated by suitable means at *right angles* with each other; the working of the top valve being dependent on the frictional contact of the two faces, due to the pressure of the steam acting on the top surface. The main valve, which is worked by an eccentric, has two ports in it at each end, through which steam is admitted, and a face port also at each end through which the steam passes to the ports of the cylinder. The cut-off valve is fitted in dovetail slides on the back of the main valve, as shown in the end view, and has two ports in it to correspond with the inner ports in the back of the main valve. There is a stud fixed in the back of the cut-off valve, and a die is fitted to swivel upon the stud, which die fits into a parallel slot in a lever, therefore the lever can slide to and fro on the die. The fulcrum of the lever is upon a stud fixed in a block that can slide to and fro in guides formed in the lid of the valve chest, and this block has a rod screwed in it which passes through a stuffing box to the exterior of the valve chest, this rod being connected with the ordinary ball governor of the engine by rods and levers or other suitable means, by which, when the speed of the engine increases, the rod will be pushed inwards, and *vice versâ* when the speed of the engine decreases. The end of the lever moves between parallel ribs or stops which stop its movement. These ribs are formed by two brackets fitted in parts projecting from the steam chest lid, so that they can be slid to and from each other, and they are secured by bolts, one for each stop. Each bolt has a small eccentric formed upon it which enters a suitable slot—shown in dotted line in the plan—in the stop, so that by rotating the bolt, the position of the stop can be adjusted, and then the bolt can be secured by the lock nuts. Upon each stop a series of thin plates are loosely secured one against the other by two screws—to deaden the shock or blow which the end of the lever gives upon the stop.

revolving gear for working piston valves, as illustrated by Fig. 150. The ports of one valve seat are opposite the intermediate or closed ports of the other valve seat, whilst the spaces or ports of one valve are opposite to those of the other. The pistons are secured on the shaft, so as to be capable of rotation with that shaft, when rotary motion is imparted to it. Traversing motion is imparted to the shaft, and consequently to the valves, by means of the eccentric on the crank shaft, or it may be by other suitable means through the connecting rod, the other end of which embraces a stud, which is capable of sliding in a slot formed for it in the stationary guide, and is formed to receive the outer end of the rod, which at that part is provided with collars and set nuts, so that it may be moved endways with any to-and-fro motion of the stud, and yet be free to revolve therein. In order that rotary motion may be given to the valves, the shaft is formed into sexagonal or other suitable form, to slide endways through a corresponding shape in the boss of the tooth wheel, and according to the arrangement shown, this progressive rotary motion, at the times and to the extent desired, is first obtained from the bevel toothed wheel on the crank shaft, the teeth of which gear into the teeth of the bevel tooth wheel fixed on one end of the pinion shaft, which is supported so as to be capable of revolving in stationary bearings, and has fixed on its other end another bevel pinion, which by means of the horizontal bevel pinion is capable of giving motion to the fifth bevel pinion fixed on one end of the countershaft, which latter is also supported with capabilities of revolving in stationary bearings, and has connected to it by a spring clutch-connection a face plate, that has a stud projecting from it in position to act upon the teeth of a star wheel, as shown in detail by Fig. 151, and the rotation of the face

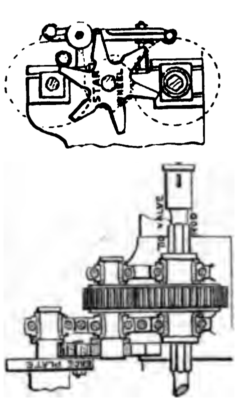
Fig. 150.



Galloway's Revolving and Sliding Motion, Valves, and Gear, for working the Piston Valves, as shown in section, patented in the year 1868.

plate imparts, "step-by-step," rotary motion to the star wheel. This star wheel is secured to one end of a shaft, which is supported in proper bearings, and has keyed upon it a spur pinion, the teeth of which take into the teeth of a spur wheel; and thus rotary motion is communicated to the valves. But that the extent of this motion may be controlled by the governor, the horizontal bevel pinion is arranged to revolve on an arm, which is formed with lugs to turn in suitable bearings coincident with the centres of the shafts, while the outer end of this arm is by a pin joint, and a suitable connecting rod linked to the governor to be operated by it, so that as the governor rises or falls the other end of the arm is actuated in one or the other direction, turning the bevel pinions partially round, thereby altering the relative movements of the spur pinions, and thus causing the stud in the plate to act sooner or later on a tooth of the star wheel, varying the cut-off effected by the valves; there are stops, also, which simply hold the star wheel in position.

FIG. 151.



Details of Galloway's Valve Gear, shown complete by Fig. 150.

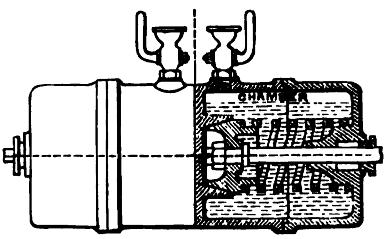
At the end of this year, 1868, Mr. Inglis patented two new dash-pots for closing the "Corliss" valves of compound or any other engines, one of them being shown by Fig. 152. It will be understood that the two portions, sectional and complete, are dupli-

FIG. 152.

bottom of the plunger is made conical to fit a conical seat formed for it in the inner end of the chamber. The plunger is connected to the valve gear by the spindle, so as to be drawn outwards when the valve is opened, and on the gear being released it moves the valve back, its own momentum being gradually checked close to the end of its traverse inwards by its having to displace the oil from the seat. Instead of the plunger or its equivalent being moved inwards by atmospheric or other equivalent pressure, the necessary pressure for that action may be applied by a metallic or other spring, the oil or other liquid being in all cases retained to prevent violent concussion at the end of the inward movement.

Figure 153 is a sectional elevation of the other dash-pot, which is a modification embodying a convenient mode of applying a metallic spring, a spiral steel spring being placed between the plunger and the cover of the chamber, and in a state of compression sufficient for forcing the plunger against its seat.

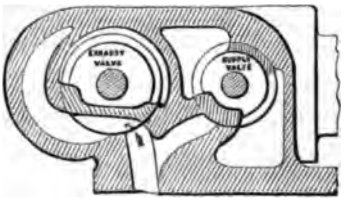
FIG. 153.



Inglis' "Dash-pots," in which the Plungers are actuated by Steel Springs and Oil, patented in the year 1868.

The next year, 1869, was rather rich in new valve gears, and the "Corliss" valves seem to have met with much attention then, for their practical application was considered novel, and of course therefore interesting; but with the use of those valves the various inventors introduced new gear, which practically nearly obviated the original kind, and also that which immediately followed it, without the advantages they possessed. What seemed to be the prevailing fashion was old "Corliss" valves with new gear for working them. As an example Fig. 154 is introduced, which is an illustration of Messrs. Holcroft and Dack's "Corliss" valves as arranged and patented by them on the 1st of April in the

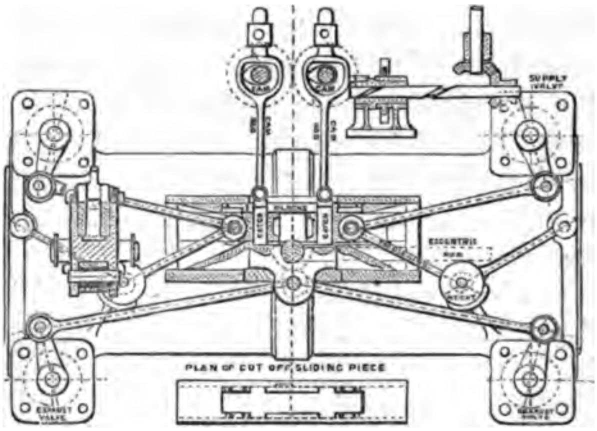
FIG. 154.



Holcroft's "Corliss" Valves for the Supply and Exhaustion of the Steam, situated together; patented in the year 1869.

year 1869, and Fig. 155 represents their gear when those valves are arranged separately or as usual. The main feature in this gear is that there are no dash-pots, but cam-motion catches and weights perform their use.

FIG. 155.



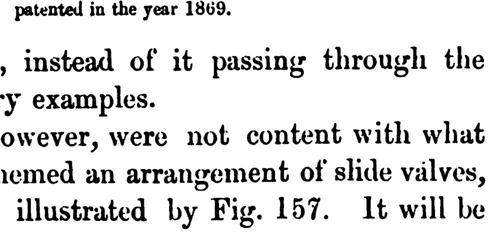
Holcroft's Valve Gear, with Catch-pins, Cam-motion Weights, and Eccentric-gear, for working "Corliss" Valves; patented in the year 1869.

This arrangement is, that at the centre of the length of the cylinder there is a slide or sliding-piece used for the actuation of the cut-off and exhaust valves, which are attached by rods without the usual clips and toe-lever gear. This slide is worked by an eccentric rod in the general way, and is fitted with flanges, shown by the end section, between which sliding blocks fit; these sliding blocks are connected to or disconengine. The end of the grooved shaft is connected to the governor either directly or by a hydraulic cylinder. The two shafts are driven by spur-gearing.

The method of operating this valve-gear is as follows:—So long as the engine is at work the eccentric rod moves the slide to and fro, and the links work the exhaust valves as usual. When the catches are down, as shown, the sliding blocks are also carried to and fro to work the valves, but as soon as the cam has lifted the catch, the sliding block is instantly brought back by the falling of the weight, which drops into a cup cast with the cylinder and lined with some soft material. The time at which the cam lifts the catch, is regulated according to the speed of the engine, by the governor which moves the shaft endwise, and in so moving, that cam is turned partly round, and thus varies the time of releasing the catch. After the catch has been raised it drops on to the side plates and is held up by them until the sliding block returns to its former position, and allows the catch to drop again into the position shown, and the operation is repeated.

Figure 156 represents another arrangement of gear. In this case also it is applied to a "Corliss" engine without dash-pots, but with the ordinary wrist plate. It is obvious that by the means now shown and that described, the force required to lift the weight or to compress a spring, as in the usual mode of closing the valves, is applied direct to the sliding blocks or wrist plate, instead of it passing through the spindles of the valves as in ordinary examples.

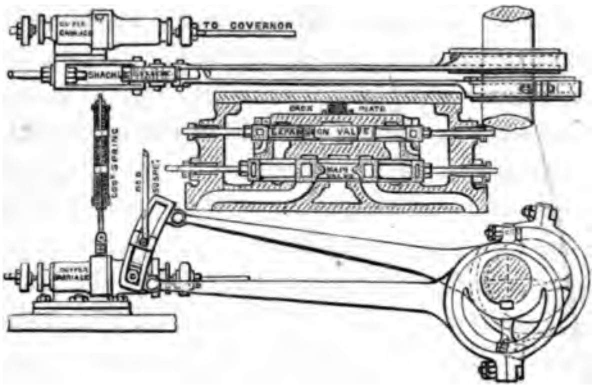
FIG. 156.



Holcroft's Arrangement of "Corliss" Valve Gear to obviate the use of Dash-pots, but use Weights in their place; patented in the year 1869.

Mr. Holcroft and his friend, however, were not content with what they did, as has been stated, but schemed an arrangement of slide valves, and link-motion to work them, as illustrated by Fig. 157. It will be seen that there are two valves, the main valve working under a block valve or frame above, within which works the cut-off or expansion valves, so that there are two back plates for the valves to work against.

Fig. 157.



Holcroft's Back-plate, Equilibrium, Expansion, and Main Slide Valves, worked by the Link Motion and regulated by a Governor; patented in the year 1859.

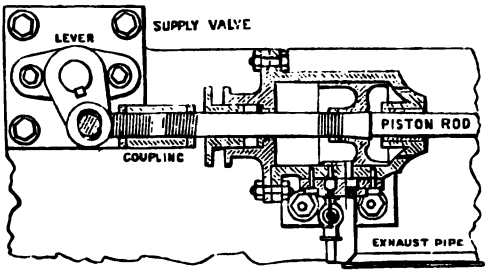
The link-motion is the usual kind, but is in connection with an arrangement of springs to close the cut-off valve quickly as well as to be regulated by the governor by a differential stop gear, which is connected by right and left-hand screwed rods to the buffer carriage and the shackle joint.

Fig. 158.

The governor spring-gear is rather peculiar, it being two spiral springs at the same angle, having between them a third spring at an opposite angle, by

But Mr. Holcroft was not alone in the field of fame for the invention of Corliss Valve Gear, however; because in the same month Mr. Rose of Lancaster patented an arrangement of dash-pot gear, as shown by Fig. 159, by which it will be seen that on the end of the valve rod a lever is keyed, and to it is attached a screw rod, fitting in a socket. This socket, being screwed internally right and left-handed, and at the latter part is fitted with another rod in connection with the piston of the "dash-pot," so that by turning it around in either direction, the connection between the lever and the piston can be lengthened or shortened as required. The piston rod passes through a stuffing box at the left-hand end of the dash-pot cylinder, and through a bush at the other. The rod has a broad piston secured on it, and in this piston there is a small port which is held opposite, or over, another port in the casing or cylinder at the termination of each sudden movement of the piston, thus allowing the steam in the casing to exhaust through the pipe shown. When the piston makes its slow forward movement, the exhaust port is covered, and the next port is uncovered, through which steam enters that may be brought by another pipe, fitted with a stop-plug valve as shown. The pressure of the steam gives the sudden return movement to the piston when the valve-rod is released, by which movement the steam port is covered, and the exhaust port is uncovered at the end of the movement. That end of the cylinder without the stuffing box is termed the dash-pot end, and air is allowed to enter through one or more small holes during the slow movement of the piston, to act as a cushion or buffer to prevent percussion or shock at the end of the return sudden movement of the piston, the air which can escape through the small hole or holes checking the blow.

FIG 159.



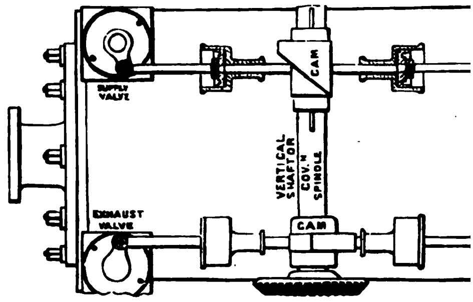
Rose's Steam "Dash-pot" and Gear for Closing "Corliss Valves," patented in the year 1869.

This patent contained also an arrangement
Corliss Valves, the main feature of which is t
each set of valves driven by mitre gearing.

Now if we turn to page 159, there is repres
arrangement of valve-gear by a Mr. Loomis,
proposes as his invention; which shows how nea
follow the steps of others, although they may be
that fact, or even intending it.

Mr. Rose's gear is represented by Fig. 160, an
from that illustration to be as follows:—To

Fig. 160.

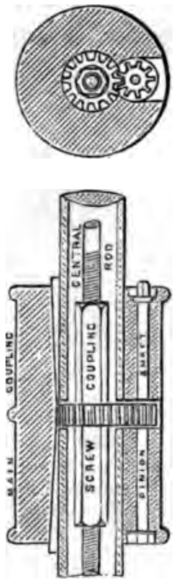


Rose's Vertical Cam Motion Gear, for working "Corli
patented in the year 1869.

oscillating valve rod one end of a piston rod is
end passes through and slides freely in a guide

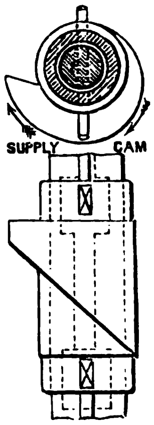
The vertical shaft is hollow, and is formed in two parts connected together by a main coupling, as shown by Fig. 161. The upper end of the shaft carries an ordinary governor, to the sliding boss of which a central rod is secured by a cotter passing through a slot in the sliding boss, the hollow shaft, and the central rod. This rod is in two parts, connected by a long right and left-handed screw coupling, as also shown by Fig. 161, the exterior of this coupling is formed hexagonal, or like a screw nut, so as to fit and slide freely through a corresponding hole in a spur wheel arranged in the main coupling between the two ends of the vertical shaft. This wheel gears with a pinion on another vertical shaft, having bearings in the main coupling, which shaft can be rotated by means of a square end, and a suitable key to adjust the length of the central rod. The lower end of the rod is connected by means of a cotter passing through it and through a slot in the hollow shaft, with a cam of peculiar shape, which can, while rotating, be slid up and down by the governor. The most elevated part of the cam is undercut, as shown in detail by Fig. 162, so as to be clear of the part acted upon when it is suddenly forced back by the valve spring; this cam acts upon the dash-pot piston rod of the supply valves at each revolution, first on one and then the other, so that by varying the position of the sliding cam, the time of cutting off the steam from the cylinder is regulated, and this is done self-acting by the arrangement described. When the speed of the engine increases above that fixed upon, the governor will slide the cam upwards, and this will release the dash-pot piston rod sooner, and allow the valve spring to shut the valve, and *vice versâ*, when the speed of the engine decreases.

FIG. 161.



Rose's Adjustable Spur Gearing Coupling for the Motion-shaft that works the arrangement of Corliss Valves and Gear, as shown by Fig 160. Patented in the year 1869.

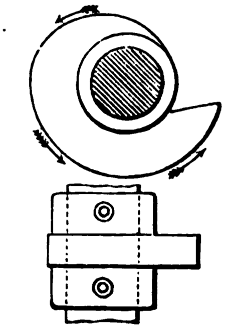
FIG. 162.



Rose's Cam for working the Supply Valves of Corliss Engines, patented in the year 1869.

Other arrangements of mechanism may be e governor with the sliding cam, and the governo other convenient position; for be slid to and fro on the s arrangement, or any other con steam engines having vertical of the cam's position may be clutch lever, and a rod with ad connected with the governor. arranged and actuated like th that the cam, as shown by Fig. vertical shaft, and it is formed t and to allow the spiral spring the end of the stroke.

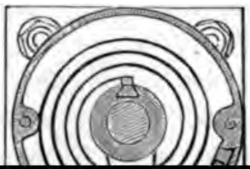
Fig. 163



Rose's Cam for working the Exhaust Valves of Corliss Engines, patented in the year 1869.

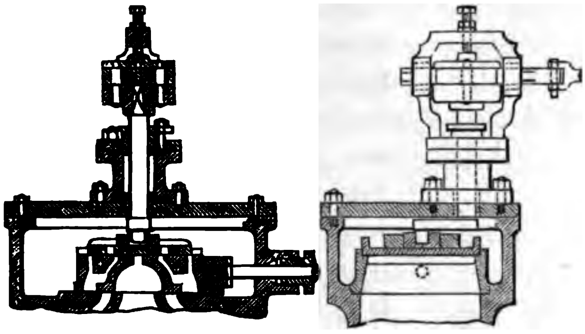
The "spiral valve spring" a Fig. 164, which arrangement i end of the spring is fixed to a key or plug, secu valve, and the outer end to a key or plug fix valve; and thus the inne outer end is fixed, and the spring imparts a sudden r required.

Fig. 164.



It will have been noticed Fig. 148 is illustrated an arr to the lever formed at the lower end of a rod that passes through a stuffing box on the cover of the valve chest. On the end of this rod is fixed a disc plate, fitted with studs with swivel blocks, these latter being provided with brass liners, between which the tapered bar, actuated by the governor, works. When the engine is in motion the slide valve tends to carry the cut-off plate with it, and the ports in the slide valve and plate are so arranged that the cut-off can be effected by stopping the motion of the plate before the slide has reached the end of its stroke. The point of the stroke at which this stoppage of the movement of the cut-off plate, and the consequent cut-off of steam, takes place, is regulated by the action of the governor, which inserts or withdraws the tapered bar between the liners of the swivel blocks, and consequently limits or increases the period of rotation of the lever rod, and so regulates the cut-off to the power required. This valve is not arranged to cut off the steam beyond one-third of the stroke of the engine cylinder piston; but three other examples, by three firms, of a similar arrangement are shown on Plate 65.

FIG. 165.

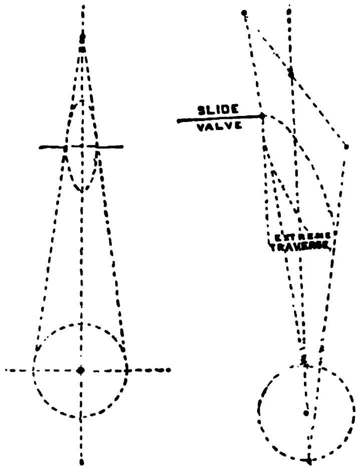


Cuthell's Patent Main and Cut-off Valves, regulated by an ordinary Ball Governor, constructed in the year 1869.

Ten years previously Mr. Hackworth of Darlington patented a very peculiar arrangement of valve gear, and improved it step by step up to this date, 1869, and the principle of this latest method is that—there is one eccentric for the slide valve of each cylinder, having a rod whose

extreme end moves in a straight line. At one
end of the eccentric rod the valve rod is attached,

FIG. 166. FIG. 167.



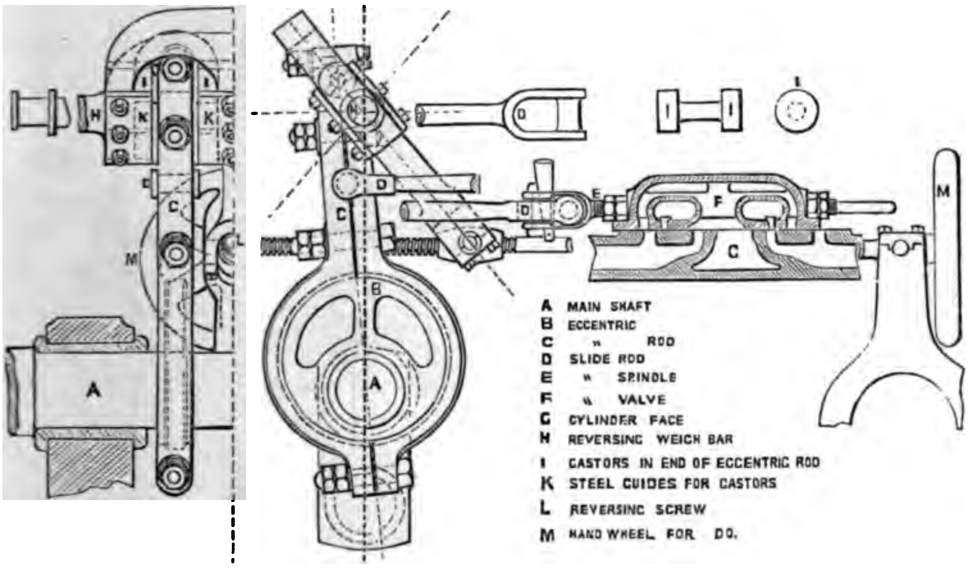
Geometrical Diagrams of Hackworth's Expansion and Reversing Gear, as arranged in the year 1869.

forming, in one revo
elliptic figure, thus
verse diameter bei
motion of eccentric
angles with the slic
and equal to lap a
this position the
way round, the ext
it is on the centr
larly the line of mot
end, the end of the
elliptic figure, but tl
is increased in propc
thus (Fig. 167), and
movement occurring
passed the centre, it
way round, or as the line in which the rod e
one side or the other of the square line for short

The arrangement of the gear and form of val
or locomotive engines is shown by Fig. 168.
movement of the valve is obtained from one ecce
performs the functions of a lever, having the val

ring when the engine is on the centre gives the lead for either way round, and determines the relative positions of the crank and eccentric. A variable traverse and reverse action is produced by causing the parallel motion to move angularly on either side of the centre line as represented by a ×, one line giving the greatest supply of steam one way round, and the other the opposite; the supply being reduced as the line of motion approaches the centre, in which position the lead motion only is in action, the traverse being suspended. When both the lead and traverse are in action, one is at the middle of its traverse when the other is at the extreme, or in other words they are at right angles with each other in all similar cases.

FIG. 168.

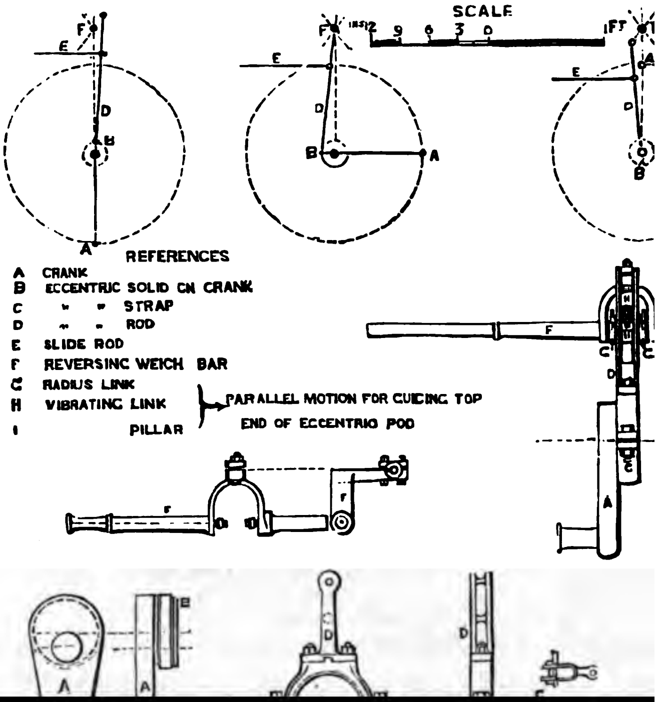


Hackworth's Single Eccentric Expansion and Reversing Gear and Valves, for Marine or Locomotive Engines, as proposed in the year 1869.

In some cases Mr. Hackworth has preferred to use a radius rod parallel motion for guiding the end of eccentric rod, as shown by Fig. 169 on the next page: this plan is very complicated and equally expensive.

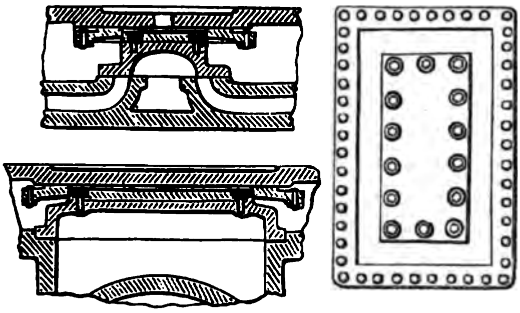
But mostly has been proposed the steel castor parallel bars for guiding the rod end, as show also been applied to marine engines, with a sl face moving on an iron guide bar.

Fig. 169.



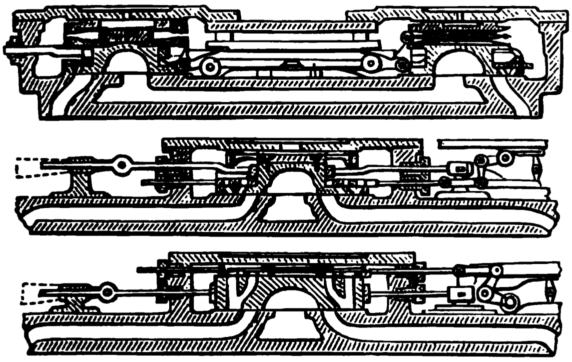
The construction of this packing will be best understood from Fig. 170, which illustrates two sectional views and a plan of the arrangement, where it will be seen that the packing is merely a spring or thin plate of metal that unites the frame plate to that on the back of the valve, so that the steam acts against the frame and the flanges of the valve at the same time; and thus the working face of the valve is relieved from the pressure that must otherwise occur.

FIG. 170.



Dawes' Elastic Spring-plate packing for ordinary Slide Valves; patented in the year 1869.

FIG. 171.



Dawes' Elastic-packing for Double-ported Slide Valves, patented in the year 1869.

The illustration, Fig. 171, shows three examples of valves having the same class of packing as before. The main valves are all double ported

for the admission of the steam, and fitted wi
correspond.

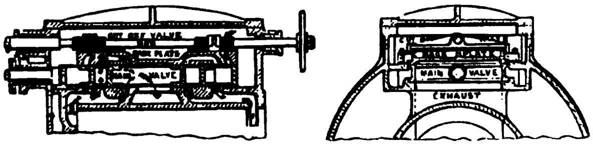
The gear for working those valves is partly sh
and the arrangement for the upper one is thus
exhaust end of each valve are fixed, by brackets,
levers, the upright arms of which are coupled—
the sides of the main valves—to the ends of the c
and between the two horizontal arms a roller is b
turned pin which is keyed into the ends of the a
levers. About the centre of the steam chest betv
fixed a differential movement of any convenient de
with the governor, so constructed that the rising
shall cause the two broad wedge-shaped pieces to
of the valve chest in contrary directions to each
governor rises they shall both move outwards fr
the valves, and as the governor falls they shall bo
the valves and towards the centre, and the positio
respect to the rollers is such that as the latter tr
valves they shall roll upon these broad wedges a
cranks and rods—close the cut-off valves alternat
later in the stroke of the piston according to
governor and the wedges. The sliding of the cut
ports at each stroke of the piston is effected

close and open them and of opposing the least angle to the roller, and therefore having the greatest power at the beginning and ending of travel of the cut-off valves when, as will be evident, the greatest power is required to move them.

In applying this compensating wedge and roller action to the valves, as shown in the second or central sectional view, the separate cut-off plates or valves are fitted upon the outer flanges of the main valve and actuated in a similar manner; the wedges, the bell cranks, and rollers, are outside the steam chest, the connection between them and the valves being obtained by rods through packing boxes in the ends of the steam chest. It is evident, also, that the cut-off valves may in this arrangement be coupled to work together as one; or the cut-off plate or valve may work upon the back of the main valve, as shown by the lower section, in the usual manner or position, and the fixed inverted or opening wedges be dispensed with on account of the closing of the ports for one side of the piston and opening those for the other at the same time.

Being now on the theme of valves we notice next Mr. Gilchrist's valves, of which the principle, and pretty much of the practice too, is as Holcroft's arrangement, as shown by Fig. 157 on page 168, where the valves are single ported, but in this case are double ported, as shown by Fig. 172, in which the cut-off valves are separate from each end of the cylinder, and are screwed on a rod with right and left hand threads, so that adjustment, by the hand wheel, can be effected while the valves are in motion: these valves work on a face or back plate, that encloses the main valve, which regulates the expansion and

FIG. 172.

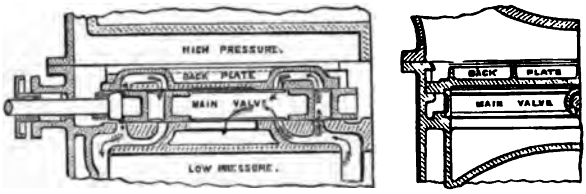


Gilchrist's Adjustable Cut-off Valves and Back Plate, and Equilibrium Main Valve for High-pressure Engines, patented in the year 1869.

exhaustion—as the arrangement is shown by two distinct sections it will be readily understood.

Mr. Gilchrist patented also the arrangement of valves, as shown by Fig. 173, which is of a more simple order than the previous example

FIG. 173.

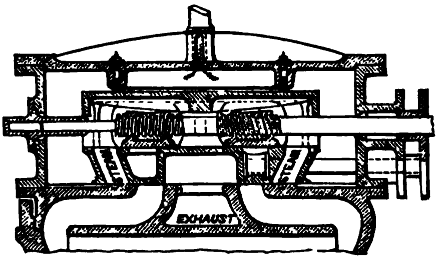


Gilchrist's Equilibrium Main Valve and Back Plate, for Compound Engines, patented in the year 1869.

and can be applied for compound engines also. The main valve for the low-pressure cylinder is single ported in its duty, and is in the form of a frame, with parallel faces with three openings through it; a narrow one at each end and a larger one in the middle. The cylinder bars are made with the exhaust port between them in the usual way, with the two ports and steam passage at the one end, and those with the other passage at the other end. The fixed back plate is made with its working face exactly like the cylinder port face, and opposite to each pair of passage ports there are two ports communicating with each other by a passage formed in the back plate. The movement of the through the passage in the back plate. The same actions of course take place at both ends, but alternately. The back plate for either arrangement may be fixed in the valve casing in any convenient way, as, for example, by taper keys or wedges which hold it between ribs formed in the sides of the casing as in the low-pressure casing, or it may be bolted to lugs or flanges as shown in the high-pressure casing. The valve of the high-pressure cylinder and its back plate, Fig. 172, have the same ports and passages as the valve and its back plate, Fig. 173, and they only differ in the additions required when applying cut-off valves.

We illustrate next, by Fig. 174, an ordinary arrangement of valves worked separately; and also by which the pressure of the steam on the back plate is reduced by a packing ring in the casing cover. The cut-off valves are in this case contained in the back plate, and the main valve below formed with the back plate is single ported. It will be noticed that this arrangement differs a great deal with that shown by Fig. 172 on page 179: there the back plate is fixed, but in this case it moves with the main valve it is a portion of: the advantage with this is, that the area exposed to the pressure of the steam can be reduced to a minimum; or, if desired, the surface areas can be so proportioned that the steam can lift the valves from the cylinder faces rather than press the valves on them.

FIG. 174.

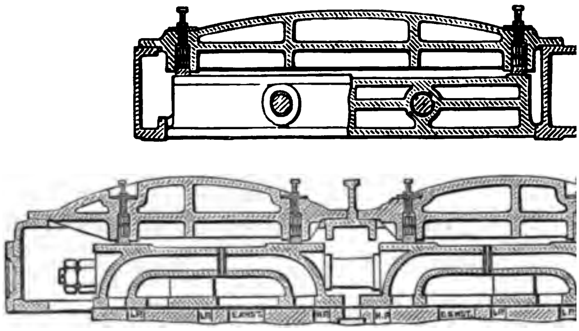


Ordinary Adjustable Cut-off and Equilibrium Main Valves for Steam Engines, applied in England and America since the year 1865.

Whilst on this subject it will be as well to allude to a new type of valve for a compound engine, constructed by Messrs. J. and G. Rennie, as illustrated by Fig. 175, on the next page. This is arranged for the uses of high and low pressures steam at the same time; the former first doing duty in the small annular space, and then performing the latter in the main cylinder. We have shown this view at half stroke, with the

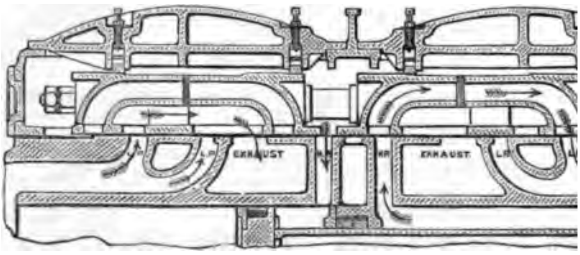
transverse section over it; but to make its utilit
ciated, it is illustrated again at full stroke by F
arrows depicting the steam's action are shown, tha
without description.

FIG. 175.



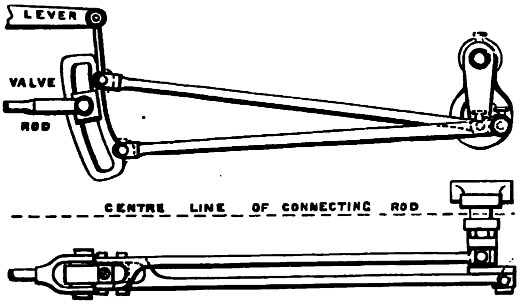
Rennie's Arrangement of Double Ported Equilibrium Slide Valves, for
Engines (Allen's Patent) fitted by them in H.M.S. "Spartan" i

FIG. 176.



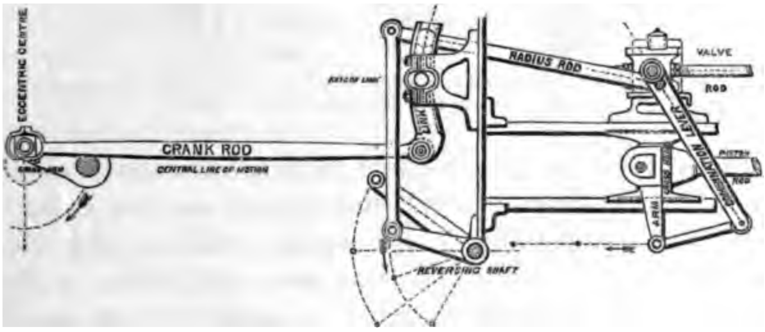
Rennie's Arrangement of Double Ported Equilibrium Slide Valves, for return crank gear also, in combination with rods and levers worked by the main piston rod, which was originated by M. Waldegg, a German engineer, as far back as the year 1857—illustrated on page 71—and since that has been rearranged, as here shown, being now termed the Walschaërt's gear, from the name of the French engineer who altered it.

Fig. 177.



Return Cranks, Link Motion, constructed at Palnan, U.S., in the year 1869.

Fig. 178.

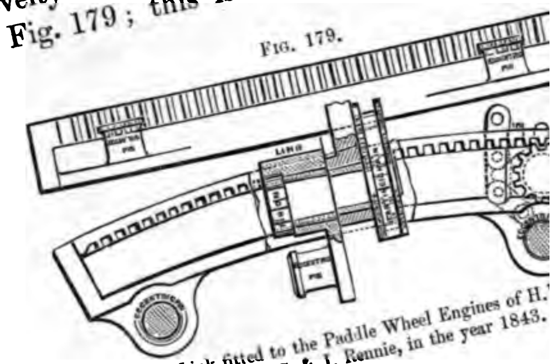


Walschaërt's Link Motion and Lever Valve Gear for Locomotive Engines, adopted mostly in Belgium during the last ten years, or since the year 1860.

The action of the gear is this: the link is hung on a pin centrally situated, and the lower end is in connection with the return crank pin, which, of course, performs the function of an eccentric. The motion of the link is transmitted by a block and rod to a valve-rod lever, and the raising and lowering of the block to the limits above and below the centre pin alters the valve "lead" from one to the other en cylinder; the valve-rod lever, it will be seen, is in connection end with a block fixed on the valve rod, and at the lower en to an arm on the cross-head of the main piston rod. The m valve is therefore alone constant from the piston rod wh block is on the centre of the vibrating pin, and exceptiona bination with that of the crank pin when the block is rais from the central position.

Another novelty of link-motion must now be referre illustrated by Fig. 179; this is the toothed type worke

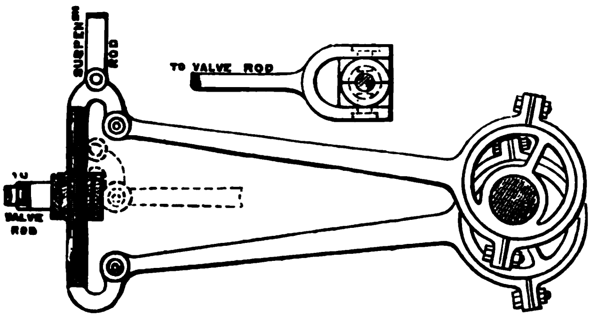
Fig. 179.



Elevations of the Link fitted to the Paddle Wheel Engines of H.
by Messrs. G. & J. Rennie, in the year 1843.

backward by a pinion that receives motion fro applied to paddle wheel, vertical direct-acting the year 1843, by the late G. Rennie, Esq., F that the link-motion was invente before, it is evid soon as joint the eccentric rods in a line with the slide valve rod, which, by-the-way, is but the common slotted link connection with that evil also.

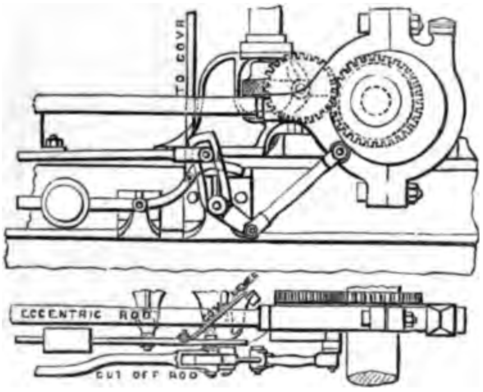
Fig. 180.



Smith's Solid Straight Link Motion, having the ends of the Link turned up and down to connect with the eccentric rods, patented in the year 1869.

Leaving the link-motion we again revert to the land engine valve gear, and direct attention to that illustrated by Fig. 181, which is an arrangement of lever motion in connection with an ordinary eccentric and ball-governor gears by Messrs. Marriott and Holt of Manchester, in which the ordinary eccentric that works the main valve, is also attached by a rod to a lever, formed with a link, while in this link is fitted a block, in connection by rods with the cut-off valve and the ball-governor sliding block, by which arrangement the latter valve is not only worked by the eccentric, but that travel is also regulated by the action of the governor raising the block in the link. The spur gearing and worm imparts the motion from the crank shaft to the governor spindle, as shown in the plan

Fig. 181.

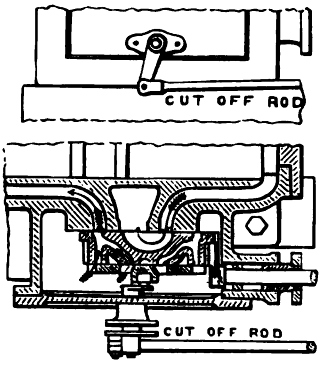


Marriott's Expansion Gear regulated by a Ball Governor, in connection with Common Eccentric Gear for working the Cut-off and Main Valves of an Engine, patented in the year 1870.

and elevation, from which views the relative pos
rods can also be seen.

Now if we turn to page 61 we shall see there

Fig. 182.

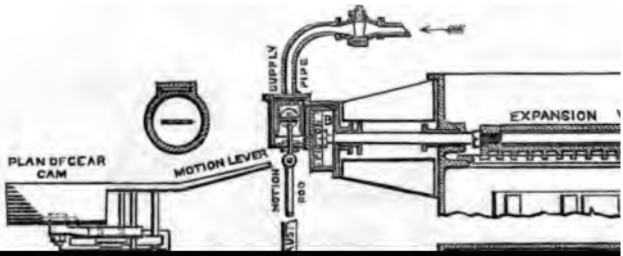


Marriott's Valves in connection with the Gear, illustrated by Fig. 181, patented in the year 1870.

his friend were fully
to their gear, and that
valves, as shown by
illustrated on page 161

Our purpose next is
trate an expansion gea
by Fig. 183, that ha
Mr. Edgar, an enginee
an ordinary cam moti
to keep the roller agai
in Plate 34, but the p
be regulated by a scre
this case: the cam-l

Fig. 183.

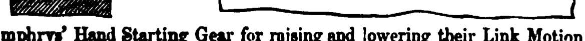


with a tubular equilibrium steam valve that regulates the flow and exhaust of steam into and from a small cylinder, having a piston in it that is driven forward and backward as the proportions and motion of the valve determines: this piston has a rod fitted through it, which is secured at the other end to an ordinary gridiron expansion valve, by which connection that valve is actuated. Now the motion of the valve, of course, depends on that of the piston, so that if the latter is driven back suddenly it causes the valve to open the ports under it, and while the piston remains still the valve does also: on the steam being admitted to the other end of the cylinder the piston is reversed in position at once and the gridiron valve closes the ports and remains in that position until the piston moves back again: the whole feature then of the arrangement lies in the "jerking" of the piston by the steam, and in order to deaden the blow, a conical dash-pot, with a suitable piston, is situated at the extremity of the piston rod beyond the gridiron valve. All this, however, has been carried out before in a better manner, as shown by Plate 39 B.

Before closing this chapter we will explain and illustrate a few novel examples of starting gears that are not shown in the plates.

Messrs. Humphrys, Tennant and Co. have for the last ten years used

FIG. 184.

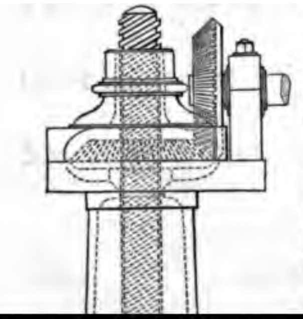


Humphrys' Hand Starting Gear for raising and lowering their Link Motion for Screw Engines; as used from the year 1862 to the present time.

the arrangement as shown by Fig. 184, which consists of pinions and a rack motion, in connection with the usual hand wheel. This firm,

although the present sole adopters of this gear,
of it, because Messrs. Maudslay, Sons and Fie
trivance eighteen years ago, but the rack was sit
of horizontally, as illustrated, and was arrange
level with the base of the engine as in both cases ;
rack is situated at the side of the feed pump chan
in the second at the side of the slide valve casing
Messrs. Maudslay used one pinion only to gea
lower end was attached to the link, and thus
wheel, the effect was accomplished, while Mess
power with less speed, used three pinions of une
as follows : centrally of the length of the feed c
fixed by a nut on the inside end, and a tube wit
it is supported on this pin ; the starting wheel
part, and thus the pin su
pinion gears with a small
which is also supported o
as the other above ; this
it a pinion that gears wi
connection with the link
kept in gear by a roller o
pinion. Obviously then
hand wheel, the pinion mo
it turns the pinion in gear

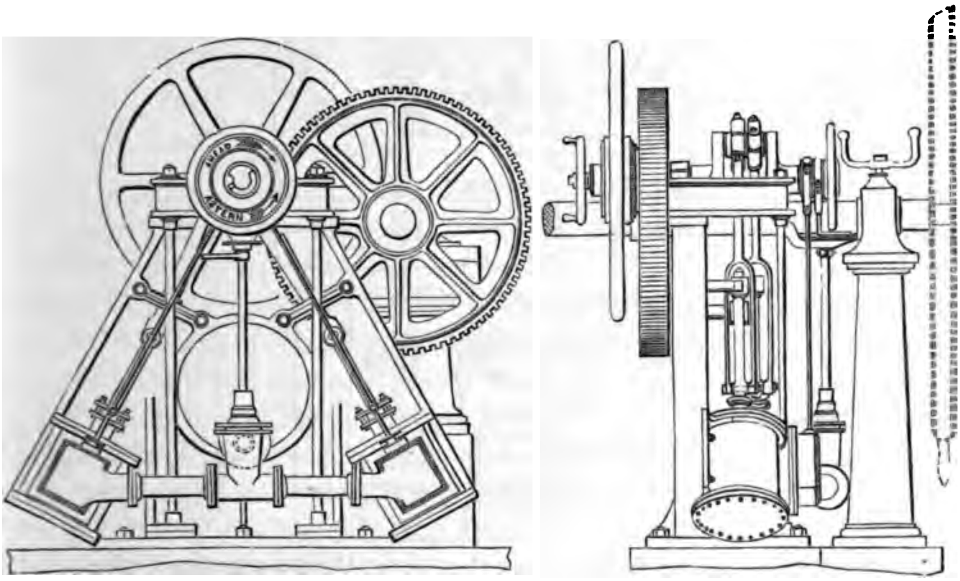
Fig. 185.



this can be arranged horizontally also with the same result, as in either case the screw rod is in connection with the link and the starting rod, that is actuated by the hand wheel.

Hand power, however, is not always sufficient with engines of large size, because the link-motion and the slide valves are very heavy and cumbersome, and to overcome or shift them, steam starting gear is employed, as illustrated by Fig. 186, and arranged by Messrs. Maudslay.

FIG. 186.

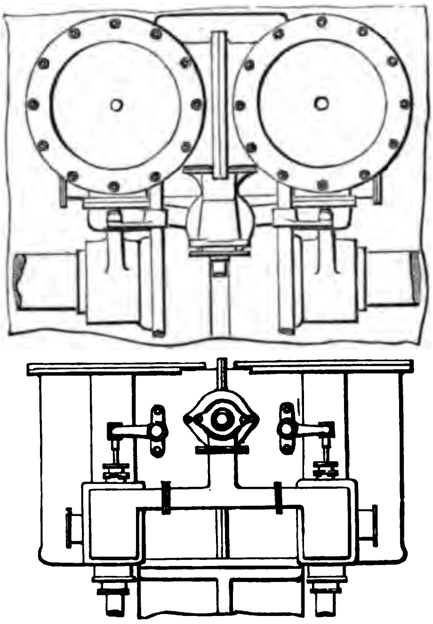


Maudslay's Steam Starting Gear, for raising and lowering their Link Motion for Screw Engines; as used from the year 1862 to the present time.

This gear consists of two angular direct-acting steam engines with single eccentric valve gear—but link-motion gear with two eccentrics have been used also—and on the engine shaft there is a tooth pinion in gear with a tooth wheel on the starting shaft, which latter has on it a hand wheel also, to be used in cases of emergency; there are also an indicating disc-fly wheel and stop clamps, or hand spanners, by which the direction of the engines are regulated.

Now, although that arrangement may seem clever and very efficacious, it has the fault of many details, which is entirely eradicated by the arrangement shown by Fig. 187, as introduced by Messrs. Ravenhill, Hodgson and Co.: here we have direct connection and action from the starting engine piston to the lever on the link weigh shaft, with the

Fig. 187.



Ravenhill's Steam Starting Gear, for raising and lowering their Link Motion for Screw Engines; as used from the year 1862 to the present time.

entire absence of spur gearing shafts and bearings and their attendant casualties. The course for the steam required to shift the pistons is regulated by hand gear-slide valves, by which means very little wrist

CHAPTER III.

THE GEOMETRICAL PRINCIPLES OF THE ACTION OF ECCENTRICS AND LINK-MOTIONS, ACCORDING TO THEIR RELATIVE POSITIONS, AS APPLIED FOR VALVE GEARS OF STEAM ENGINES.

INTRODUCTION.—The principles of valve-gearing mechanically change so much with the arrangement of the details, that calculations, unless relative to those circumstances, are useless. Yet with this, as a known fact, we have in a certain work on valve gears calculations given, in which all the problems of Euclid and algebraic formulæ possible are involved, and this would not be out of place, indeed, if our working engineers were educated up to that standard; but as they are not, then all the crossing of lines, fine writing, and symbols are lost for practical purposes, and their use only serves to astonish rather than instruct their readers. The answer to this may be, "educate your men to meet the case;" but even were this possible, then those geometrical rules and calculations, in nearly every instance, would be useless in practice; and "practice," it must be remembered, is the main point; in fact, the climax of all our endeavours and study.

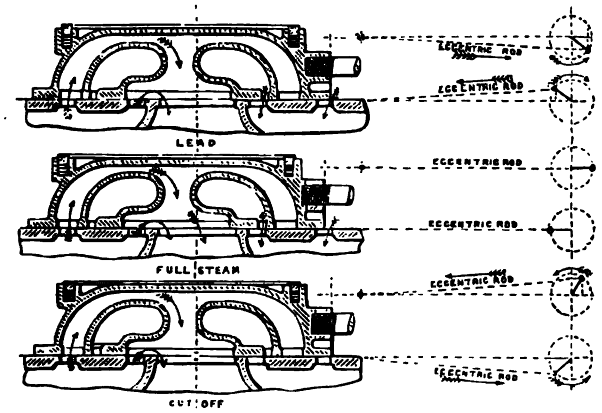
What then is required, is plain simple geometry of the same class and order represented as the engine is intended to be; that is, don't put in supposititious events or occurrences to disturb the proper action, but settle first the best *practical* means available, and work to that only; keeping in mind all the requirements for adjustment and repair. Now those two last features are the very things that we who are practical notice first, and the very things that the heavy c at all; and why is this ?—it is the result of plain c by hard study and genuine substantial thinking, the soaring of the aspiring imagination of tho please themselves when in their own element of s

PRACTICAL PRELIMINARIES.—To begin this pr the travel of the valve, next the length of the e form of the link, after that how to suspend it, and versing gear. Now all those four functions for motion, and unless their relative proportions ar taken into account in the geometry and calculat must occur. The travel of the valve settles the t the length of the rods determines the action of sides of the centre of the shaft; on the form of loss of motion given by the eccentrics, and the s is also accountable with that; while the kind of the expansion duty of the link as well as the pow it. But to fully explain all those particulars pra sider first the valve and eccentric motions and certain lengths of eccentric rods.

The illustration, Fig. 188, shows a slide valve kind, in the positions for lead, full supply stea length of the eccentric rod and the relative an

Now the eccentric's travel and rod are subject to the same cause, therefore the effect must be the same as already stated. Turning to the diagrams again for further explanation, Fig. 189 represents the circle of an eccentric travel, 11 inches in diameter, the lead for the valve being ½ inch, outside lap 4 inches, width of steam supply opening, caused by the valve, 1½ inch, and length of eccentric rod only 36 inches. Next, notice that the length of the chord intersecting at the parts of the circle nearest the valve, is shorter than the one opposite; hence the versed sines, V V, are, in relation to that circumstance, also due to the radius of the circle being unalterable. The valve having an equal lead when the piston arrived at each end of its stroke, the points L L are due to the length of the eccentric rod, which determines an unequal position for the angle of the eccentric above, and below the

FIG. 188.



Diagrams of a Slide Valve, Eccentric, and Rod, at their forward and backward positions; for lead, full steam and cut-off, when the length of the Rod is 5½ times the travel, and the lead $\frac{1}{30}$th of the same.

FIG. 189.

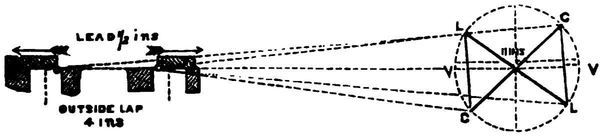


Diagram of the positions of the Eccentric and Valve for lead (L) and cut-off (C), when the length of the Rod is 3⅓ times the travel, and the lead $\frac{1}{22}$ of the same.

centre line. Here it must be remembered that th
moves with the crank, and no relative alteration
but it is essential in the present instance to assum
due to the length of the eccentric rod, if an even l
points, C C, are the angles of the eccentrics when
off the steam, and as the arc, L V, above the ce
to V L below opposite, so also will V C above and

Compare next the diagram, Fig. 190, with the

Fig. 190.

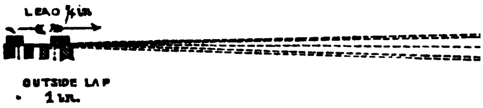


Diagram of the positions of the Eccentric and Valve for lead (L
when the length of the Rod is 14$\frac{3}{8}$ times the travel and the

Here the eccentric's travel is only 3$\frac{1}{8}$ inch, the la
width of opening $\frac{9}{16}$ inch; but the eccentric r
inches long, so that L V and V L are nearly equal,
similar comparison with each other, and make but
the versed sines. In Fig. 189 the lead is $\frac{1}{8}$th of t
this case the lead is quarter of the lap, while the
are nearly equal to each other.

Fig. 191 is another proportion; the outside lap is

Fig. 191.

It is further demonstrated by the diagram, Fig. 192, that the versed sines of the crank and eccentric are alike in proportion. It is seen when the crank has passed through equal arcs, also the eccentric, that the chords and versed sines are relatively equal, but the grades of expansion, P P, are, of course, unequal. We shall understand this better from the diagrams, Figs. 193 and 194. The cranks, C C, are shown in opposite directions, and the angles of the eccentrics, E E, due to the lead required; when the crank in Fig. 193 is rising, the eccentric is descending, as shown by the arrows, and reverse in Fig. 194. Another fact is, that this unequal grade of expansion is also due to the connecting and eccentric rods being on the same side of the crank shaft, so that the arcs of position, for both piston and valve, are in the same direction. This is the fault with all direct-acting engines, and although the fault may be remedied by unequal laps and leads, the principle of the action

FIG. 192.

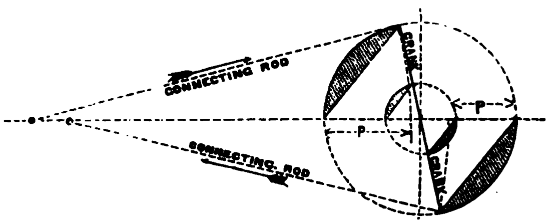


Diagram of the angles of the Crank and connecting Rod, for an unequal Grade of Expansion; but equal versed sines of travel for the Crank-pin and centre of the Eccentric.

FIG. 193.

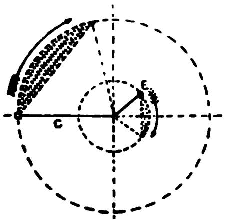


Diagram of the angles of the Eccentric for lead and cut-off by the Valve, when the Crank is at the left hand.

FIG. 194.

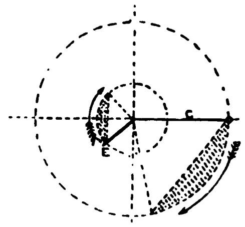


Diagram of the angles of the Eccentric for lead and cut-off by the Valve, when the Crank is at the right hand.

remains the same; hence this axiom, "that if lea
of the stroke, expansion must be unequal at bo
with direct-acting engines."

Now, having shown the bane, we will produce
the diagrams, Figs. 195 and 196. This is the

FIG. 195.

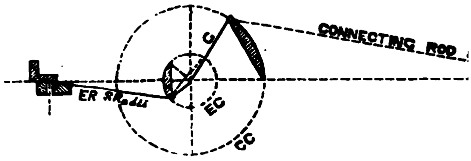


Diagram of the relative positions of the Slide Valve and Guide-
connecting-rod, to produce an equal lead and equal grade
each stroke of the piston: the lengths of the Eccentric and
of the same proportion to their travels.

FIG. 196.

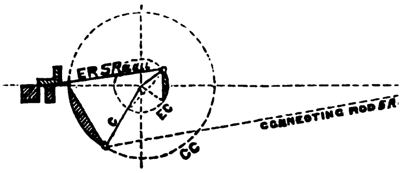


Diagram proving the application of the proportions. Sho
in a reverse position.

engine as far as the positions of the connecting-

The slide-valve is situated opposite the connecting-rod, and the length of the eccentric-rod E.R is five radii of the eccentric circle. The arcs of the valve's position are thus relative, in a contrary direction to those for the piston. Those arcs, therefore, being proportionate, but in opposite directions, a relative action must be certain.*

LINK-MOTION.—When the link is used as a medium between the ends of the eccentric and valve rods, the principles just explained remain as before, as far as the positions of the eccentrics and length of their rods are effected; but the motions of the ends of the rods, instead of being sliding only, have the additional movements of rising and falling also, or vibrating to and fro, so as to form cross-curve lines, which will be fully explained hereafter.

We will now investigate the difference in the positions of the link when the rods are crossed, and not crossed, in order to lead up to final matters for correct conclusion.

The diagram shown by Fig. 197 is a sectional elevation of a double

FIG. 197.

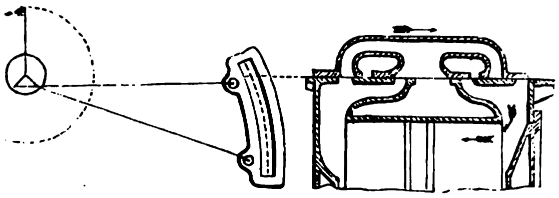


Diagram of the Link-Motion and Slide Valve, with the Eccentric Rods *crossed* and the Link " down," for direct action, the Valve " cutting-off."

FIG. 198.

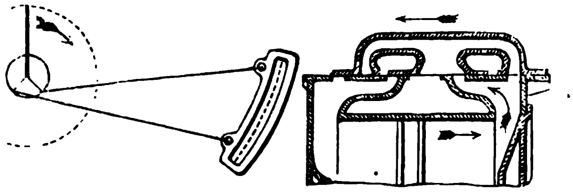


Diagram of the Link-Motion and Slide Valve, with the Eccentric Rods *not crossed*, and the Link "down" for direct action, the Valve " cutting off."

---

* This was explained first by the author in a lecture at the Society of Arts in December, 1867.

ported slide-valve and portion of a cylinder to cor
in a certain position, due to the eccentric rods b
crank vertical; producing therefrom an unequal
the piston, which, of course, should be avoide
eccentrics and link, as shown by Fig. 198. It will
relative positions of the links and valves are en
other; as, for example, in Fig. 197, the top of the
the shaft, but in Fig. 198 it inclines towards the
ments of the crank and valve are in reverse directi

The next illustration, Fig. 199, shows the link a
half stroke, when the eccentric rods are crossed a
and Fig. 200 illustrates the same details with t

FIG. 199.

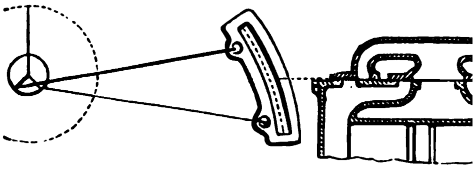


Diagram of the Link-Motion and Slide Valve, with the Eccentric
Link "midway," for direct action; the Valve at "hal

FIG. 200.

owing, of course, to the eccentric rods being crossed in the one case and not crossed in the other. We next direct attention to the uniform positions of the links in Figs. 197, 199, and 201, all inclining towards the shaft, and as a contrast, to those shown by Figs. 198, 200, and 202, inclining towards the valve, which is the right way as much as the other is the wrong.

FIG. 201.

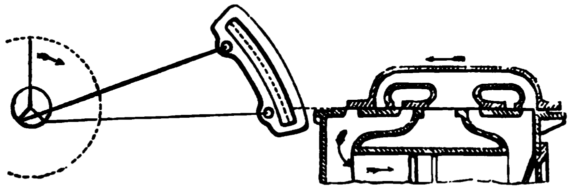


Diagram of the Link-Motion and Slide Valve, with the Eccentric Rods *crossed*, and the Link "up" for direct action: the Valve "cutting off."

FIG. 202.

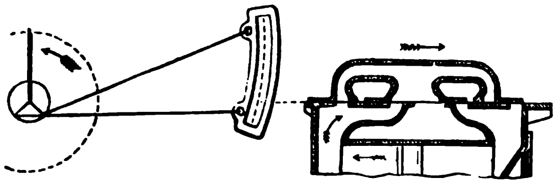


Diagram of the Link-Motion and Slide Valve, with the Eccentric Rods *not crossed*, and the Link "up" for direct action: the Valve "cutting off."

ADJUSTABLE ECCENTRICS.—Having thus far investigated the performances of the fixed eccentrics, we will now explain the duties involved with adjustable eccentrics; as, for example, in the diagram, Fig. 203 on the next page, the eccentric has an angular advance of $33\frac{1}{2}°$ or a position C F, suitable for a positive or forward motion of the crank if a lever intervenes between the eccentric and the valve. It must be understood, also, that the same eccentric, when situated at an opposite angular advance C B, holds a position appropriate to a negative or back motion of the crank. Hence if it be required to change the direction of the engine's motion, it is only necessary to

unkey the eccentric, slip it around the shaft, an
a position C B, opposite to that of C F.

But if in addition to a change of direction a v
for the forward and back motions of the crank w
to the single condition that the lead opening and
altered, then it would be very clear that the ecce
in such a manner that its centre can pass in a *di*
instead of following the arc F *m* B. By this m

FIG. 203.

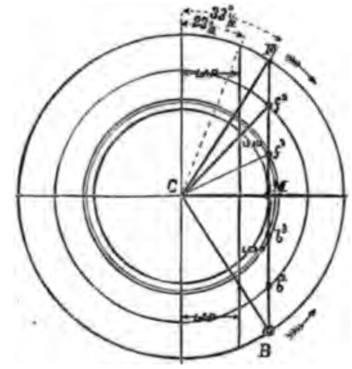


Diagram of an Adjustable Eccentric's travel-circle, with *constant* lead.

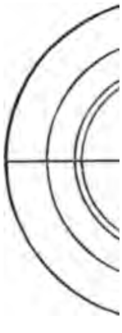


Diagram of an
circle,

eccentric, and consequently the travel of the val

Suppose next that C F, the radius of the eccentric circle, or full throw of the eccentric, is 2½ inches:

Then the greatest travel of valve . . . = 5 inches
Suppose the lap . . . . . = 1 „
And lead opening . . . . . = $\frac{3}{8}$ „

These dimensions are chosen on account of no peculiar fitness in their relation to one another, but merely to illustrate the effect of reduced travel, constant lap, and a variable or constant lead upon the cut-off, lead angle, port opening, and exhaust closure of a simple slide valve.

With a *Constant Lead opening* the centre of the eccentric should be moved in a direct line from F to B, Fig. 203. When situated at F, the travel of the valve equals twice C F = 5 inches, the lap = 1″, and lead = $\frac{3}{8}$″; if now we mark the lap and lead on a slip of paper, and apply it in the usual manner, we find that

The cut-off = 123° = 0.77 stroke.
The lead angle = 10 degrees.
The port opening = 1½ inches.
The exhaust closure = 146½° = 0.92 stroke.

Upon removing the centre of the eccentric from F to f^2 the travel will be reduced to twice C F^2 = 4″. Lap and lead opening remaining unchanged, we find, by applying them to the 4″ travel, that

The cut-off = 106° = 0.64 stroke.
The lead angle = 14 degrees.
The port opening = 1 inch.
The exhaust closure = 136° = 0.86 stroke.

Since b^2 is removed the same distance from B that *f* is from F, the two positions f^2 and b^2 will give precisely the same results for opposite motions of the crank.

In a similar manner the cut-off, etc., for the p may be readily found, but their mutual relation car grouping their results in a Table like the following

Constant Lead.

Eccentric's Positions.	Travel.	Lap.	Lead opening.	Cut-off.		Lead angle.	Port opening.
	Deg.	Deg.	Ins.	Deg.		Deg.	Deg.
F or B	5	1	$\frac{3}{8}$	123	=0·77 stroke.	10	$1\frac{1}{2}$
f^2 or b^2	4	1	$\frac{3}{8}$	106	=0·64 ,,	14	1
f^2 or b^3	3	1	$\frac{3}{8}$	71	$=\frac{1}{3}$,,	25	$\frac{1}{2}$
M	$2\frac{3}{4}$	1	$\frac{3}{8}$	$43\frac{1}{2}$	=0·14 ,,	$43\frac{1}{2}$	$\frac{3}{8}$

Again, with *Variable Lead opening*, diminishing towards the full gears (from $\frac{3}{8}''$ to $\frac{1}{8}''$) the centre move in the arc of a circle, as shown in Fig. 204, w are drawn a little nearer towards the centre o reducing the travel of the valve. A Table simi been constructed for showing the effect of the actic

Variable Lead.

Eccentric's	vel.		l opening.	Cut-off.	l angle.	opening.

I. That whether the eccentric centre be moved along a straight line, or upon an arc, the nearer its approach is to the mid gear, the cut-off and exhaust closure will take place the earlier; while the lead angle and angular advance of the eccentric will be increased accordingly.

II. At the mid gear—

The port opening = the lead opening of the valve.
Cut-off angle = lead angle of the valve.
Angular advance = 90°.
Hence the exhaust closes at the ½ stroke.

III. If the port opening = 0, in the mid gear, then the lead opening = 0, and the lead angle = 90°. The steam consequently is not admitted to the cylinder for either stroke of the piston.

IV. Since the free admission of the steam depends directly on the area of the port opening, and this is gradually reduced towards the mid gear, it must be evident that the *most influential* element upon the perfect action of a link motion, or adjustable eccentric, will be this width of lead opening in the mid gear; at which position it should equal the port opening.

V. Whether the lead opening remains constant or varies from the full to the mid gear, the lead angle—or angular distance of the crank from the nearest centre at the moment the port commences to open for the admission of steam—*increases* in maguitude from the full to the mid gear. At this point, if the lead opening = 0, the angular distance becomes = 90°. This condition is of course incompatible with motion, for the port opening being 0, no steam can enter to urge forward the piston; but could this be moved to the 90° or ½-stroke point by sudden independent motion, it would then be repelled by the steam admitted for the support of the return stroke.

VI. To estimate, therefore, the effect of any lead on the continuity of the crank motion, it is necessary to know not only the width of the lead opening (or lead) at the end of the stroke, but also the angular distance of the crank (or lead angle) at the moment lead commenced. In other words, we must know the *area* of the opening and the *time* required to produce it. Thus with a constant lead of ⅜ inch the por commenced opening for the full gear when the crank was within 10° o the end of the stroke, but for the mid gear when the crank was withi 43½° of the same position, a portion of time nearly 4½ times greater fo the same opening.

The relations between travel, lap, lead, and port opening for th different positions F, f^2, f^3, M, b^3, b^2, B of the eccentric, are conveniently illustrated by a diagram, Fig. 205.

Describe the travel-circle *a'* F B, lay off on both sides of the centr or exhaust-closure line *c'* C, the la and lead, and draw the cut-off and lead lines. Through the various positions F, f^2, etc., draw indefinite lines parallel to the central line o motion *a' d''*, and upon these lay of on each side of the exhaust-closur line the ½ travel for the position in question. Thus, from *c'* lay off *c'* and *c' a* each equal to C F the ½ travel; from c^2, c^2 *h* and c^2 *e* eac equal to C f^2, and so on. Finally draw the curved lines *d* M d^2, *a* M a^2 through the extremities of the travels for their boundary lines. The

FIG. 205.

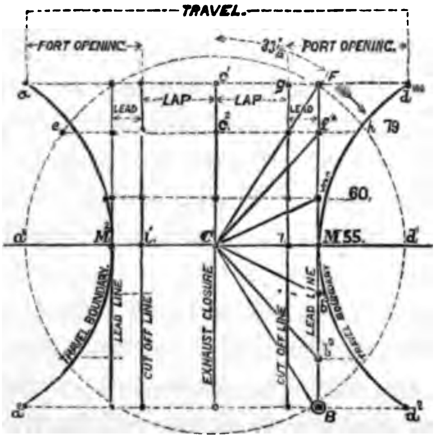
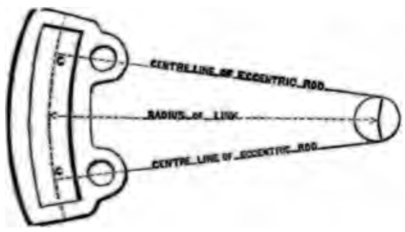


Diagram of an Eccentric's travel-circle in relation to lap, lead, and port opening, at various angles of the Eccentric.

Practical Geometry of the Link-Motion.—The first step in this matter is the radius of the link, which, for the slotted form, is produced as shown by Fig. 206. The chord of the arc C, C, is the virtual length of the link or the limit that determine the positions of the eccentric rods and pins in the link which connects them together; this length is of no fixed rule, but may be from twice to thrice the stroke of the eccentric, as desirable with relation to other matters which are explained further on; in the present case the length is three times the stroke. The method of drawing the link as shown is this: First draw a horizontal line termed the radius of the link, which length is agreed on from practical conclusions in connection with the arrangement of the engine—the limits of this length or radius are the centre of the link and that of the crank shaft; from the latter as a centre describe the dotted arc C, C, from the centre of the arc's length; or where it intersects with the radius or horizontal line, set off the points C, C, equidistant; then draw the circle representing the travel of the eccentrics around the centre of the shaft as the centre; draw next tangental lines intersecting at C, C, that represent also the eccentric rod's centre lines when the eccentrics are *loose* on the shaft; set off from C, C, the centres of the pin holes, and thus the geometry of the link is completed; after which the outline is merely a matter of proportion and design.

Fig. 206.



Geometrical diagram of the formation of the Slotted Link.

The "loose" angles of the eccentrics are produced from using the length of the rods as radii intersecting with the travel circle and the pin holes as centres; the length being from the latter to the centre of the shaft, and lines from that point to the intersections represent the angles required for the eccentrics when loose.

The link being drawn, our next step is to describe its application in combination with its connected details, which is shown by Plate A.

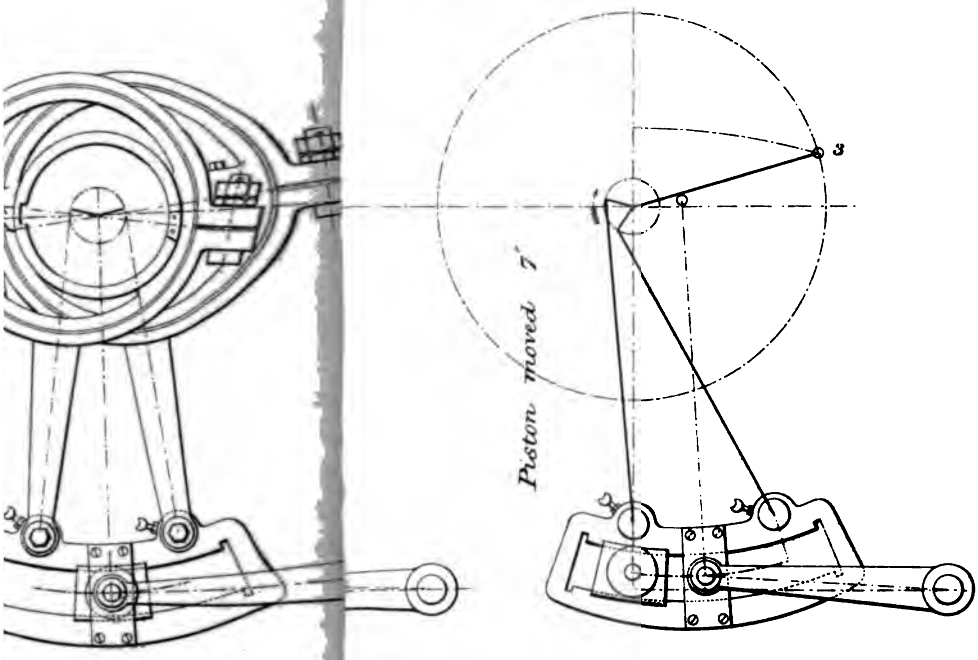
The first complete view shows the eccentrics loo connected to the link which is midway hung or in the lifting rod; this rod is attached at the belonging to a block that surrounds a screwe Plate 30. This complete view in Plate A settles al vertical centre line of the lifting rod, which is, it w to the curve or arc of the centre of the link when are in the positions represented. This centre l produced as shown, from the law of equilibrium positions of the several working parts connecting a screw-block or a lever is used to shift the link the centre line of the lifting rod is a vertical t curve of the link when all parts connected are mid

Thus far the position of the lifting rod is the by the first view, and the next view shows the when midway, but the eccentrics keyed or *fixed* or end of the lifting rod, it will be seen, has shif from the vertical centre line; the crank is horizon are at the angles for "lead."

The method of determining those angles is thu the centre of the crank shaft a circle equal in dia the valve, or the radius equal to the throw of the

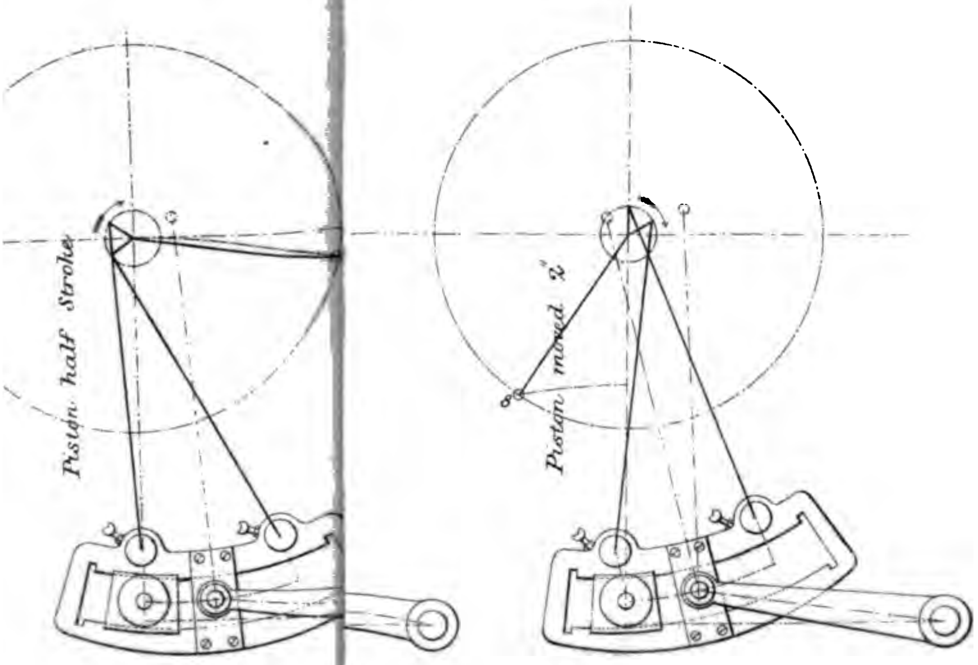
Draw the centre line of the crank at the agreed angle or horizontal or vertical; prolonging the ce

URGH.



of Connecting Rod 4'.6" link
of Piston 2'.0" 1'.3"

Lead of Valve 3/16"
Width of Steam Opening caused by Valve 3/16"
Outside Lap 3"



Feet

hes.

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raw lines to the centre of the circle, which lines are the angles of the ccentrics, and the cuttings their centres of formation at those ngles: after which their outlines can be drawn.

Having now determined the angles of the eccentrics, next with heir formation-centres as centres, and the length of the eccentric rods s a radius, describe arcs about, and above or below—as agreed on, for he link's position, whether it is up or down or midway—the horizontal entre line. Next with the lifting rod's length as a radius, and its ower end's position as a centre, describe an arc, cutting the vertical entre line of the rod's normal position; referred to before.

Now this *arc* is the leading geometrical feature that demonstrates the action of the link and its position, for every angle of the eccentrics and crank; and when drawing the link-motion, when the eccentrics are shown fixed on the shaft, the draughtsman must always take into consideration that arc *first*, because through it the suspension pin passes forth and back, and in no other path or movement; hence this axiom—the suspension pin of the link always works in an arc, the radius of which is the length of the lifting rod; therefore the greater that length the lesser the vibration of the link up and down.

Knowing now what the centre of the link is subject to in this case, our next step is to explain how to draw it in position, as shown in this figure, which is very simple because the link is midway, and it is merely that the preceding outline is repeated; but when the third figure has to be constructed, or with the link down and the piston at full stroke, the process is very different; being thus:—Repeat the formation of the eccentric circle and angles of the eccentrics; set down the screw-block end of the lifting rod from the normal position equal to the length of the chord of the virtual limit of the link, which is the centre for the radius of the arc, through which the suspension pin moves; draw next constructive arcs, with the eccentric-centres as centres, and the length of the rods as radii, and thus the *central* points of the link are defined. Then all that remains is to practically connect the link, rods, and suspension pin, and to do that *best, trace the link* from

either of the two preceding figures, and use the
were actually constructed, lay it on the arcs all
centres of the eccentric rods and suspension pins,
those arcs, prick their positions through the tı
outline of the link can be easily drawn as before.

Now there is *no error* with this method becaus
of doing it, for all suppositions are omitted, and
circumstances are taken into consideration, exact
when constructed, and that is what should be carı
office in all cases.

The remainder of the figures in this Plate aı
constructed as that just explained; and the last fc
of using a longer link, but all the other limits be
and direct from that we come to Plate C, whic
two links in various positions, but also the sli
ports of the proportions mentioned all drawn
before. Here we have a more direct conclusion
not only see what the link is doing from the actic
also the action of the slide valve in connection.

To begin with we have drawn the two links
the eccentrics keyed for lead and the crank on t
have also divided each "curved limit" of the link
but into four divisions for contrast from the extı
means is shown how the valve is effected by the
when in those positions; as for example, the shoı
has shifted the valve $\frac{1}{4}$ inch bare from lead, wheı
shifted it $\frac{3}{8}$ inch full from lead: which difference
long and short link when the crank is on the hc

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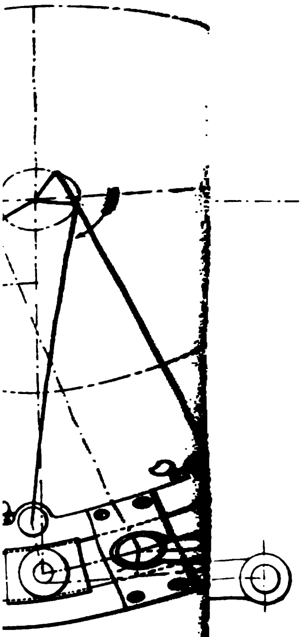
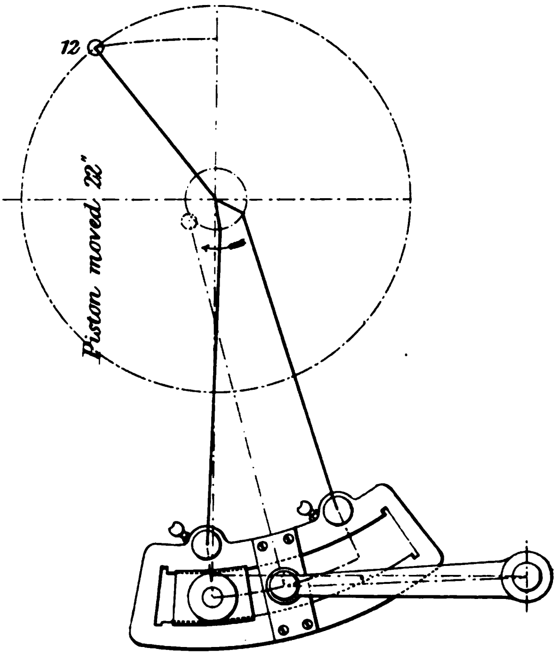
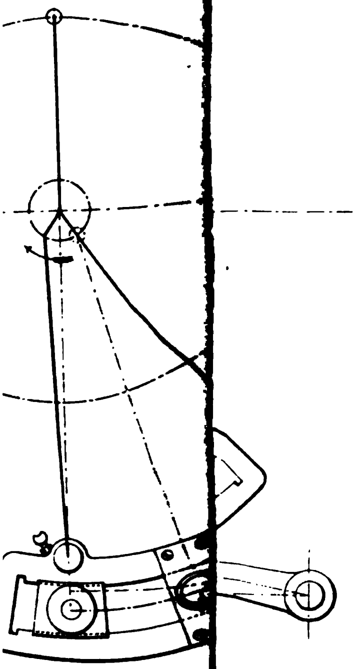


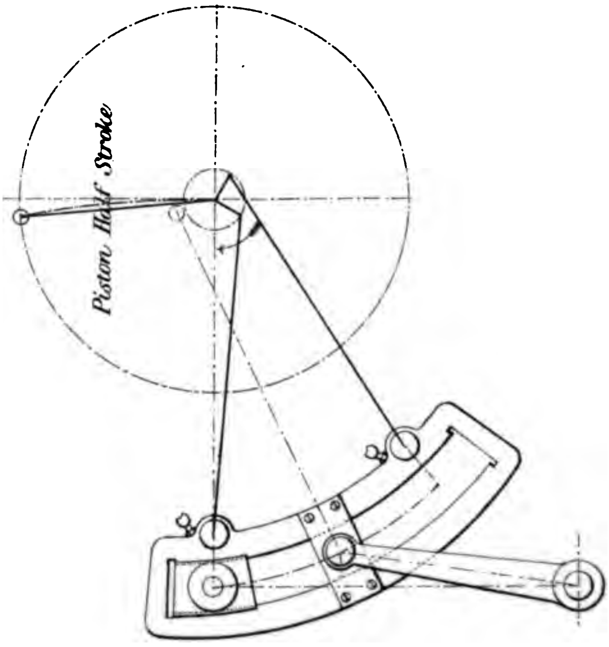
th of Connec

ke of Piston



Lead of Valve $\frac{1}{16}$"
Width of Steam Opening
caused by Valve $\frac{9}{16}$"
Outside Lap 3"





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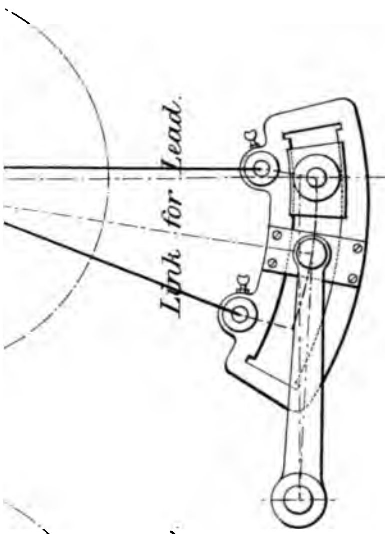
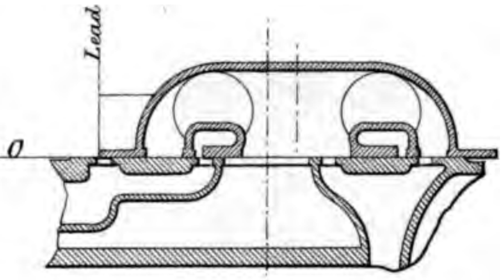
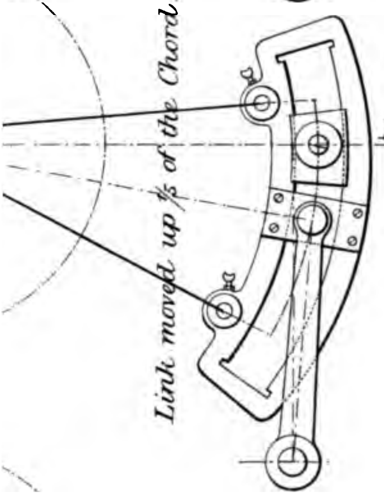
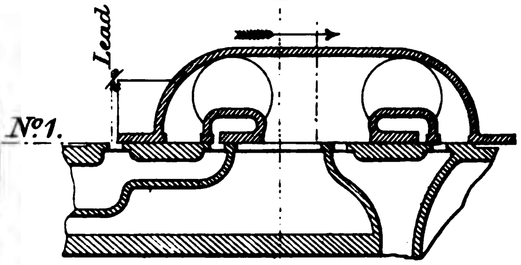


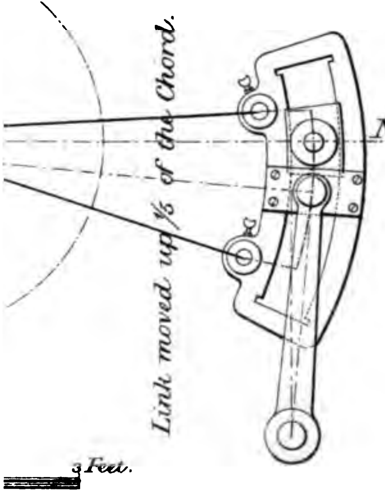
Valve lead 3/16



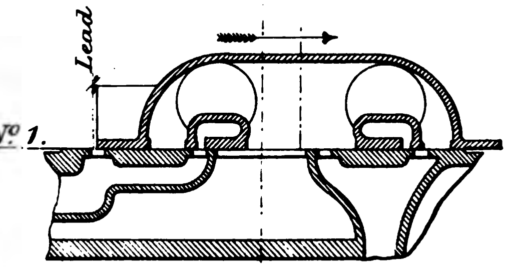


Valve moved from lead 3/16





Valve moved from lead 1/8



3 Feet.

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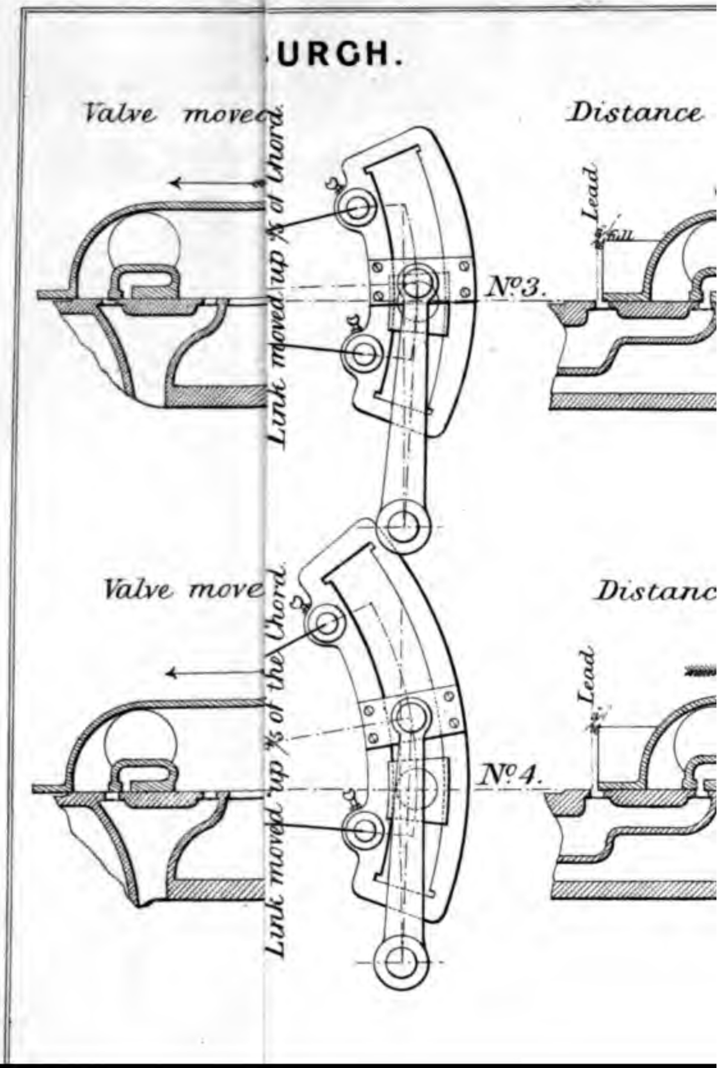
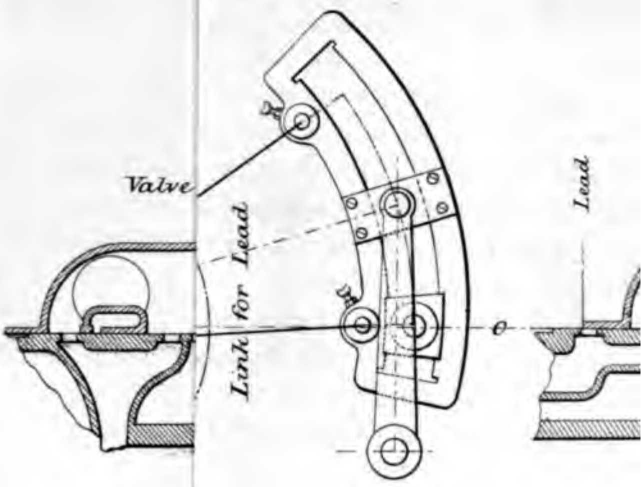
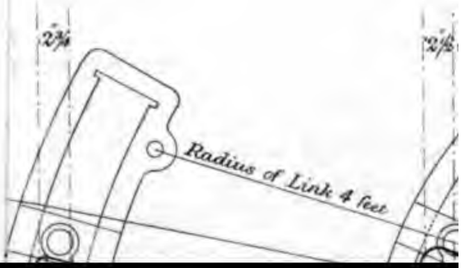

URCH.
Valve moved
Link moved up ⅛ of Chord.
Nº 3.
Distance
Lead
Valve move
Link moved up ⅗ of the Chord.
Nº 4.
Distanc
Lead

P. BURGH.





Referring next to Plate D, it will be seen that when the short link is raised to division 2, the valve has moved from lead $\frac{3}{16}$th inch; whereas with the long link in the same position, the valve was shifted $\frac{5}{16}$th inch. The diagrams illustrative of division 3 show the results as similar, because the links are suspended as much above as below the centre line. The same relations occur with the diagrams No. 4, which correspond with those shown by No. 1 on Plate C.

We have from those results this axiom. The length of the virtual limits of the link, when three times the stroke of the eccentric, actuates the valve better than less that length: but beyond that gauge there is no advantage for reversing, starting, or stopping the engine except under exceptional conditions.

Now those conditions are, the length of the eccentric rods, lap of the valve, length of the suspension rod and form of the link; but taking the matter in round numbers for every-day practice the rule given is a constant one for links of the form illustrated.

Of course with links jointed at the extremities the proportion alluded to is entirely thrown out, as the diagram, Fig. 207, illustrates.

FIG. 207.

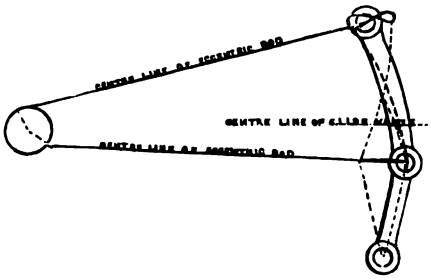

CENTRE LINE OF ECCENTRIC ROD
CENTRE LINE OF SLIDE VALVE
CENTRE LINE OF ECCENTRIC ROD

Diagram showing how the travel of the Valve is reduced from that of the Eccentrics when the Link is jointed at the extremities.

Here it will be seen that the extreme movement of the link on the centre line of the valve's action is reduced, because the eccentrics impart motion to the extremities of the link that are situated *beyond* that line; while at the same time the suspension point is at the lower end of the link instead of at its centre; by which connection, when the link is down only, the most direct action is performed from the eccentric to the valve.

Alluding next to Plate E, it will be seen that the lower half of it contains a series of diagrams, illustrating three examples of link-motion under two conditions of working: those on the left hand are examples showing the differences in the results of suspending the link down and midway, when the crank is horizontal and the eccentrics keyed on the shaft for lead, with three links of separate radii; of two, four, and six feet; proving that the movement of the block is reduced in proportion as the radius of the link is increased.

The diagrams on the right hand illustrate three links of the same radii, with the crank perpendicular and the eccentrics at the same relative angles as before, but the links up and down; showing thereby the relative distances the block-pin will be shifted by those circumstances of movement for the links.

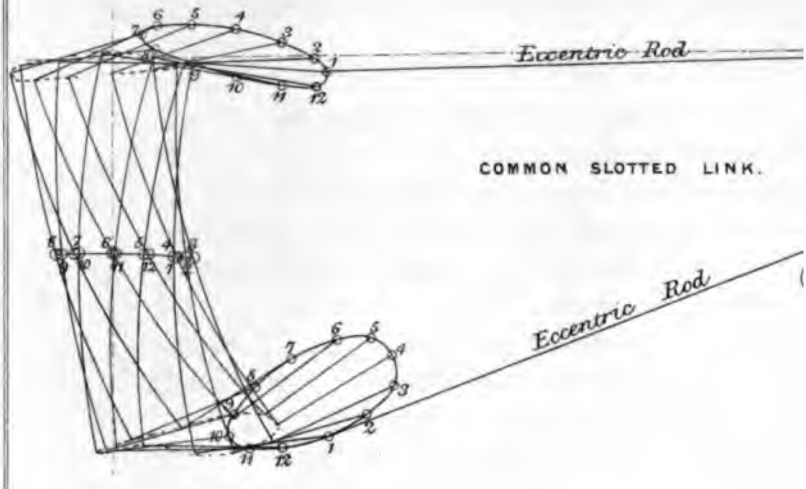
The student has now information sufficient given here to enable him to draw the Geometry of the Link Motion under any circumstance of position and proportion, by remembering the following axioms:—

I. The radius of the link is produced from the distance between the centre of the block and shaft, when the eccentrics are loose on it and the link midway.

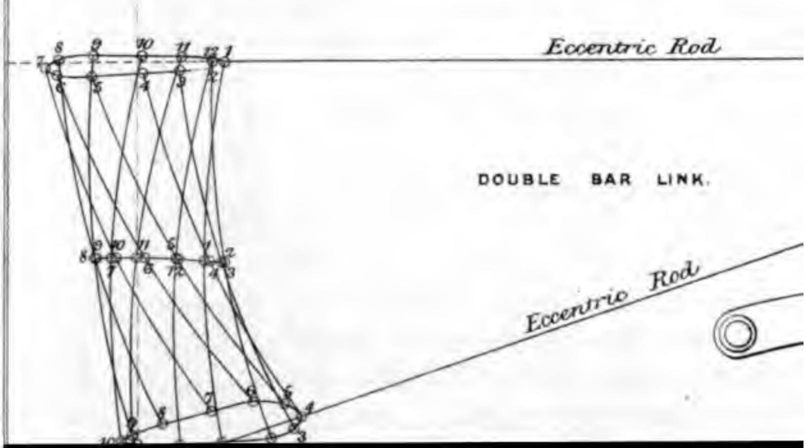
II. The length between the centres of the eccentric pins should never be less than twice the stroke of the eccentrics, and need not be more than three times; but the longer the link is proportionately, the more the valve can be shifted, *i.e.*, from the positions when the link is down, to when midway, and from there when the link is up.

III. The shifting of the valve by the raising and lowering of the link is governed mostly by the angles of the eccentrics and position of the crank; as for example, the valve is moved least by the link when the

THE GEOMETRY OF THE VIBRATIONS OF 3 DIFFERENT L



COMMON SLOTTED LINK.



DOUBLE BAR LINK.

can be found; always remembering the length of the eccentric rods are equal, and the link's centres are constants.

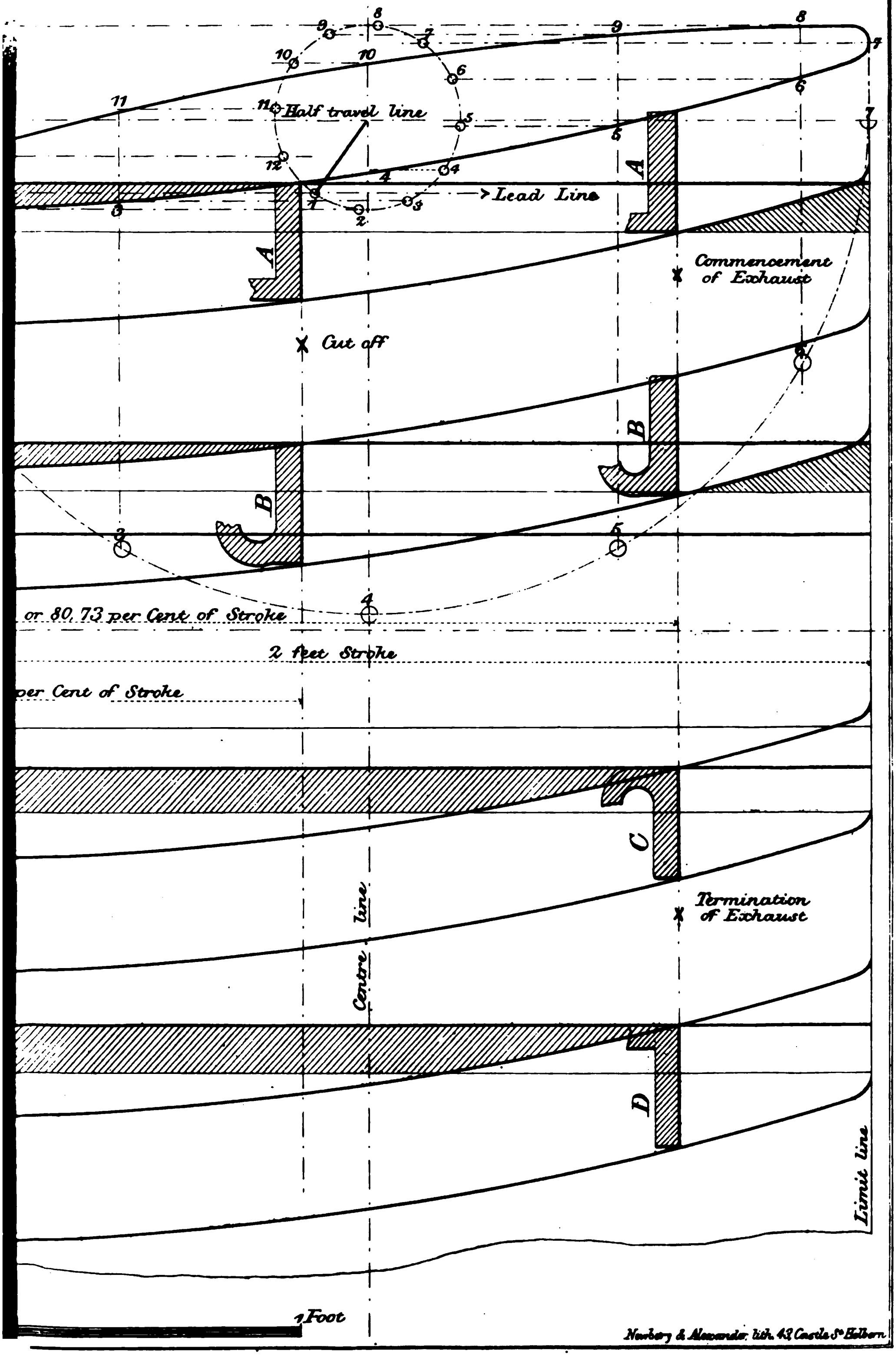
The application of this method is shown by Plate F, which is the geometrical delineation of the performances of three classes of links; the "common slotted," the "double or single bar," and the "end sliding link;" produced in the following manner.

The eccentric travel circles are divided into twelve equal parts for each eccentric, and numbered respectively, then with the length of the eccentric rods as radii, describe arcs, and number them relatively, draw in the arc of the path of the suspension pin; next, with a tracing of the centres of the link, form the curved figures representing the motions of the two eccentric pins at the ends, and thus the performance of any point in the link can be seen and understood; the geometry of the motion of the "end sliding link" is much the same, with the exception that the lower end moves in a straight line where it is suspended.

For the solid or slotted link, jointed beyond the block at each end, as shown by Fig. 207, on page 209, the method is exactly as explained, so that a repetition is not required.

GEOMETRICAL DELINEATION OF THE ACTION OF A DOUBLE PORTED SLIDE VALVE.—The geometry of this is shown by Plate G, and the method of producing it is thus:—set out on a line the ports and bars belonging to the cylinder in proportion to the dimensions agreed to, and on that line, which is a "face" line, those for the valve when in position for "lead." Next draw the remainder of the valve, if desirable to make that subject clearer, from the face line. Set off as much of the cylinder as requisite to understand that portion, and then draw a limit line, from that line set off the stroke of the piston to the same scale, and draw another limit line parallel with the other, and between those lines "square" and draw the "port" and "bar" lines of the cylinder: bisect the limits and draw a centre line. Next from the "lead" end of the valve set out a distance equal to the travel of the valve and join those points with a semicircle, the centre of which is joined to the "centre line" by the half-travel line; this last intersection is the to construct the geometrical curve of the valve's action; ar describe a circle equal to the travel of the valve; from t valve draw a line, termed the "lead line;" and where it i the travel circle is the centre of the eccentric for "lead" w is vertical or at full stroke. From that intersection divide twelve equal parts, and from its centre describe a semicircl the half travel of the crank pin, which is divided into respectively numbered as shown, with projecting lines ab the half-travel line, numbered from one to twelve; th line 1 intersects with the projecting line 1, so will 2 and and 3, and so on to the end, as illustrated. Next, throu intersections, draw the elliptical figure shown by a thick line represents the proportionate movement of the valve piston; as for example, when the bars A and B have covered the ports, they cut off the steam, which point is 39·58 per cent. of the 18-inch stroke and 43·8 per cent. stroke of the piston; and those bars permit exhaustion 80·73 per cent. respectively, while the bars C and D m sponding direction and terminate exhaustion at the given other end of the cylinder.

N OF A DOUBLE PORTED SLIDE VALVE BY N.P. BURGH.



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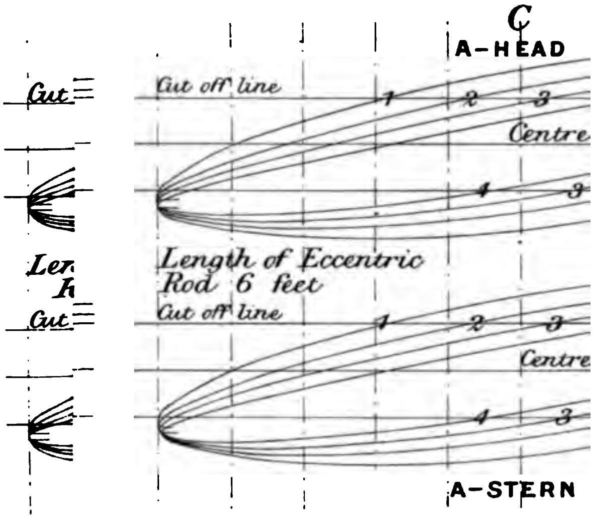
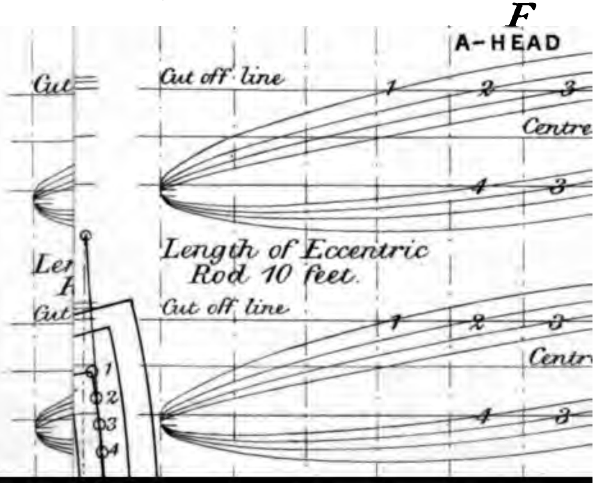
E VALVE BY MESS^{RS} JAMES W





demonstration is always the better, we have introduced the Plate H, which Messrs. James Watt and Co. kindly prepared for this work specially at our request, in order to put this matter in as clear a light as possible. These diagrams are made by an arrangement of mechanism that produces their length to scale as the stroke of the piston and their heights similarly to the stroke of the valve.

The link-motion used is the slotted kind, suspended at the centre and connected within the radial line at each end between the limits of the link as shown. The "cut-off" lines represent the edges of the ports at each end of the cylinder, and the centre line bears the same relation to the "lead" as in our diagram, Plate G. The points numbered 1, 2, 3, and 4, on the cut-off lines, refer to points on the link numbered the same, and show, by their connection, the points of cut-off obtainable with the same valve, link, length of suspension rod, and throw of eccentrics, when the link is down and up to Nos. 1, and raised and lowered to the points 2, 3, and 4, above and below the centre line for ahead and astern duties.

The distances of the points, 1 above and 1 below the centre line in the diagram A from the ends of the same, are very unlike; so much so, that the link, when down for "ahead" movement, permits the cut-off above the centre line at No. 1, to correspond with No. 3 below the centre line and the link up to No. 3, also points 2 and 4 above and below are nearly duplicate in position from their respective limits. There is very little corresponding variation, either with the diagrams for astern motion with the link up at No. 1, and at the points 3 below and with 2 above and 4 below the centre line.

It will be understood, therefore, that the link's positions in all those cases regulate the cut-off by the same valve, and that when we refer to numbers of points of cut-off, they correspond with the numbers of position for the link. Those results refer to eccentric rods six feet long and the link with one foot between centres of pins; and next we come to B diagrams, resulting from the link being one foot six inches long; where the points of cut-off are all later than with A set; although the

throw of eccentrics, lap of valve, and lengths of e
rods are constant.

C diagrams are much the best result, becaus
between centres of pins, and the points of cut-
position. F diagrams also correspond pretty clos
is the same length, but the rods are four feet lon
the link similarly lengthened; while J diagrams
of link, but twice the radius and length of rod
nearly with C. All the remaining diagrams, of
due proportion; but C shows the best result from

We come next to the question of lead, knowin
when the link-motion is used as an expansion ge
off is by the link's motion, the more lead will be
the travel of the valve; or as the link is raised to
the lead increased.

It will be seen on each of the set of diagram
ends, there are two *short* lines above the cut-off
line, and on the left hand two similarly short lin
off line, all four projecting towards the right-ha
lines indicate the points of lead for the Nos. 1
link, the other corresponding four having bee
confusion. Observe that the lead in diagrams A
and that the lead for No. 4 cut-off is much more i
that the lead is effected mostly in the former case

that description is really unnecessary; but perhaps it will be well to point out the main features for the benefit of students, taking first Plate 64 into notice. The slide-valve is shown at the position for lead, and the points on the port line numbered 1 to 8, are the points of cut-off, while those above, relating to the *inside* edge of the valve, refer to the corresponding points of exhaustion: this plate is in itself the most perfect explanation of the duty of a slide-valve that can be; and the profession owes much to Mr. Berkley for his kindness in permitting it to appear here; the same acknowledgment applies also to the other Plate 64A, which is equally useful and easily to be understood.

We notice next the performances of the "straight" link-motion, as shown by Plate 56, the arrangement of which is, that, on the reversing shaft A are forged two arms B and C, on opposite sides of the shaft, the front arm B being connected with the valve rod D, and the back arm C with the link E, by means of suspending or sustaining links in the ordinary manner. As the arms B and C are on opposite sides of the reversing shaft, the vertical movements given to the valve rod, with the link block at its extremity, and to the link are in opposite directions; and their simultaneous movements, but in opposite directions, compensate for the curvature of the ordinary link, and consequently a straight link is substituted, the construction of which is simpler than that of the curved link.

The front arm B of the reversing shaft is made longer than the back one C, in such a proportion that, for any motion of the reversing shaft, the link E and the eccentric rods move through 3-5ths of the vertical space described at the same time by the link block and the valve rod D. On moving the gearing out of the position of midgear, shown in the figures, into the position of full forward gear, the link block moves upwards through a distance of 2½ inches, the effect of which is to give the valve rod an obliquity that is equivalent to shortening it up 1-10th inch. But at the same time the link moves downwards through a space of 1½ inch, and the obliquity of the forward eccentric rod F is thus diminished to an extent that is equivalent to lengthening it out

1-10th inch. Thus the shortening of the valve rod is exactly compensated for by the lengthening of the eccentric rod, and the valve will consequently remain stationary, causing the lead to be unaltered. Similarly, when the engine is thrown into the position of full backward gear, the same compensation takes place between the valve rod and the backward eccentric rod G, and the valve remains stationary. In order that the lead may remain constant in the same manner in the intermediate positions of gear, the correct form of the link ought to be two equal curves, concave towards the valve rod, having their extremities in the same straight line with the centre of the link, the curvature amounting to not more than about 1-32nd inch, for the dimensions of gearing as shown. The error arising from making the link straight, instead of curved in the above manner, causes therefore a total variation of not more than 1-32nd inch in the lead of the valve, and the lead may therefore be considered practically constant, at the same time that the straight form of link has an advantage in simplicity of construction, and more especially in facility of repairs.

The vertical movement of the link being 3-5ths of that of the link block, the total vertical movement of the link in reversing is therefore only 3-8ths of that in the shifting link motion; and the vertical movement of the valve rod and link block is 5-8ths of that in the stationary link motion; the length of the reversing lever is thus proportionately greater. The arrangement of the single rectangular bar link-motion, *Distribution of Steam by Straight Link-Motion.*

Stroke of Piston .	**24 inches.**	**Inside Lap . .**	**Line and line.**
Common Slide Valve		**Steam Ports . .**	**$1\frac{3}{8}$ inch × 12 inches.**
Outside Lap . .	**1 inch.**	**Exhaust Port . .**	**$2\frac{1}{2}$ inches × 12 inches.**

Number of Notch.		Lead of Slide.		Travel of Slide.	Total Opening of Slide to Steam.		Point of Cutting off.		Exhaust opens and Compression begins.		Period of Expansion.		Period of Compression.	
		Front Stroke.	Back Stroke.		Front Stroke.	Back Stroke.	Front Stroke.	Back Stroke.	Front Stroke.	Back Stroke.	Front Stroke.	Back Stroke.	Front Stroke.	Back Stroke.
		Inches.	Inches.	Inches.	Inches.	Inches.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Forward Gear .	7	$\frac{5}{16}$	$\frac{5}{16}$	$4\frac{1}{2}$	$1\frac{1}{8}$	$1\frac{3}{8}$	75	72	91	90	16	18	9	10
	6	$\frac{5}{16}$	$\frac{5}{16}$	4	$\frac{7}{8}$	$1\frac{1}{8}$	68	67	89	87	21	20	11	13
	5	$\frac{5}{16}$	$\frac{5}{16}$	$3\frac{3}{4}$	$\frac{3}{4}$	1	63	63	87	85	24	22	13	15
	4	$\frac{5}{16}$	$\frac{5}{16}$ bare	$3\frac{5}{16}$	$\frac{5}{8}$	$\frac{13}{16}$	55	56	84	81	29	25	16	19
	3	$\frac{5}{16}$	$\frac{5}{16}$ bare	$3\frac{1}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	44	46	80	77	36	31	20	23
	2	$\frac{5}{16}$	$\frac{1}{4}$ full	$2\frac{13}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	31	34	73	70	42	36	27	30
	1	$\frac{5}{16}$	$\frac{1}{4}$ full	$2\frac{11}{16}$	$\frac{5}{16}$	$\frac{3}{8}$	21	23	65	61	44	38	35	39
Mid Gear	0	$\frac{5}{16}$	$\frac{1}{4}$	$2\frac{9}{16}$	$\frac{5}{16}$	$\frac{1}{4}$	10	10	50	46	40	40	50	54

The Cutting off, Exhaust, Expansion, and Compression, are given in per centages of the stroke **of the piston. The Lead is set equal in forward** and backward full gear. The Front Stroke **is from the buffer plank towards the firebox.** The Fore Eccentric Rod is coupled to the **bottom of the link.**

RULES.

Slotted Link-Motion.

Area of slide block pin = area of valve rod × 1·25.

Sectional area of each bar of link (square) = area of valve rod × 2.

Thickness of block beyond pin's diameter =

$$\frac{\text{pin's diameter}}{5 \text{ to } 7}$$

Thickness of flanges of block =

$$\frac{\text{pin's diameter}}{7 \text{ to } 9}$$

Length of sliding block = diameter of pin × 2·5.

Distance between centres of eccentric rod's pins = stroke of slide valve × 2·5 to 3.

Area of eccentric pin = area of slide valve rod × 1· to ·875.

Area of eccentric rod at centre = area of slide valve rod.

Width of eccentric rod **at** link end = diameter of pin × 1·25.

Taper of eccentric rod = $\frac{1}{4}$ to $\frac{3}{8}$ inch per foot in length.

Area of securing bolts to eccentric band = area of valve rod × ·7 to ·6.

Thickness of **T** head = diameter of securing bolts.

Solid Link.

Area of solid link = area of slide valve rod × 2·7 to 2·5.

Thickness of link = diameter of valve rod × 1·25.

Length of sliding block = width of link × 1·5.

Thickness of block, front, back, and sides = width of link × ·3 to ·2.

Diameter of projections = diameter of valve rod.

Length of projection = diameter of projection × ·7 to ·6.

Width of portion secured to valve rod = diameter of projection × 2.

Diameter of securing studs (3) =

$$\frac{\text{diameter of slide valve rod}}{2 \text{ to } 3}$$

ECCENTRIC, BANDS, RODS, BOLTS, &c.

Diameter of valve rod = diam. of piston rod × ·4.

Area of solid link pin = area of valve rod × ·7 to ·8.

Area of band bolts = area of pin × ·75.

Width of band = nut across angles × 1·03.

Thickness of boss of eccentric =

$$\frac{\text{diameter of crank shaft}}{6 \text{ to } 8}$$

Thickness of rim and arms = thickness of boss × ·75.

Depth of recess $= \dfrac{\text{rim thickness}}{4 \text{ to } 5}$

Width of rim, arms, and boss − depth of recess × 2 + width of band.

Thickness of band, wrought iron = diameter of bolts × ·6, gun metal × ·75.

STARTING OR REVERSING GEAR.

Diameter of wheel at centre of handles = 2 feet 6 to 3 feet 6 inches.

Height of centre of handle from starting platform = 3 feet 6 inches.

Length of handles = $4\frac{1}{2}$ to 6 inches.

Diameter of handles at neck = 1 inch.

Diameter of handles at extremity = $1\frac{1}{4}$ to $1\frac{3}{8}$ of an inch.

Diameter of bosses for handles = diameter of handle at neck × 2.

Thickness of rim of wheel = diameter of handle bosses.

Depth of rim = thickness of rim × ·75.

Width of arm at rim = depth of rim.

Taper of arm $\frac{1}{4}$ inch per foot.

Diameter of wheel shaft = diameter of slide valve rod.

Diameter of boss for shaft = diameter of shaft × 2.

Diameter of weigh shaft of spur segment = diameter of wheel shaft × 1·25.

When two starting wheels are used the area of each shaft = the area for 1 wheel × ·75.

Ratio of pinion or worm to segment = 4 or 6 to 1.

Pitch of teeth in inches = diameter of slide valve rod × ·8 to ·5, using the latter for the greater ratio.

REVIEW.—We have thought it best to conclude this work with a review of what has been done in it, rather than do that in the preface; knowing that the preface is always looked at by charlatan critics as the field from which they reap their harvest of technical language, when reviewing a work they can never understand; which, while doing, is done with an illegitimate air of profound wisdom, so that the general reader may be deceivingly refreshed with the apparent draught of superior knowledge poured out to him. In another way, an empty critic will find fault with everything, and ridicule the best portion that has cost the most time and trouble to produce, without even offering any suggestion; and the conceit with this vacancy of knowledge is founded on the delusion that all critics are infallible, while it really happens often that the reviewer of a work knows very little of the subject, and from that ignorance condemns it mechanically.

We commenced this work with the "History of the Invention of the Link-Motion," and having settled that question, the next subject we explained is "The Principles of the Action of Steam-Working Valves;" those are fully investigated for the benefit of the student, so that he can understand—if he will—the meaning of the words, lead, cut-off, expansion, and exhaustion. The two former terms relate to the valve, but the latter to the steam; in the same chapter also is treated, at some length, the action of one volume of steam in the cylinder.

Our next chapter is a matter of history combined with remarks of a practical nature, bearing directly on the efficiency of any example dilated on. One great historical truth may be mentioned also, it is, that there has been no improvement in the link-motion since the year 1843, and that every conceivable form of link and connections have been carried out since then to displace the original arrangement. Expansion gears have had their share of attention too, but for moderate speeds, nothing yet has been introduced that supersedes the cam-motion of 1821; for the shape of the cam can be made to work the valve quickly and slowly in the same revolution, which the eccentric does not perceptibly do. Valves, of course, put in, as it may be, a warlike appearance against the gear, under the direction that the gear might be imperfect, but the valve was not, and thus one advantage was gained at least; the rule there being; cut-off by the valve's design, and not by the motion of the gear; as, for example, in many cases *three* faces were introduced, all in working contact; all to be kept steam-tight, and all said to be required for one operation. It is but fair to our leading firms to say they have kept out of those extreme measures; following rather the dictates of common sense than "airy" conclusions.

The practical method of treating all mechanical arrangements—and valves and gear in particular—is to prepare for "wear and tear," for when that is omitted the downfall of the proposition soon follows as a matter of course.

The best kind of slide valve for general duties is the double ported equilibrium; packed at the back with a ring the same size and shape in outline as the face limits.

The most perfect link-motion yet introduced is the arrangement with the eccentric rod pins in the centre of the link's width; and when the link is up or down, that point is the centre of the block-pin; by which means the vibration is the least, and always equal—up or down—when the link is suspended at the centre of its length and width.

The present favourite expansion gear is the eccentric and slotted lever, in connection with a "gridiron" or multiple-ported valve.

Starting or reversing gears have not improved much since the year [redacted]

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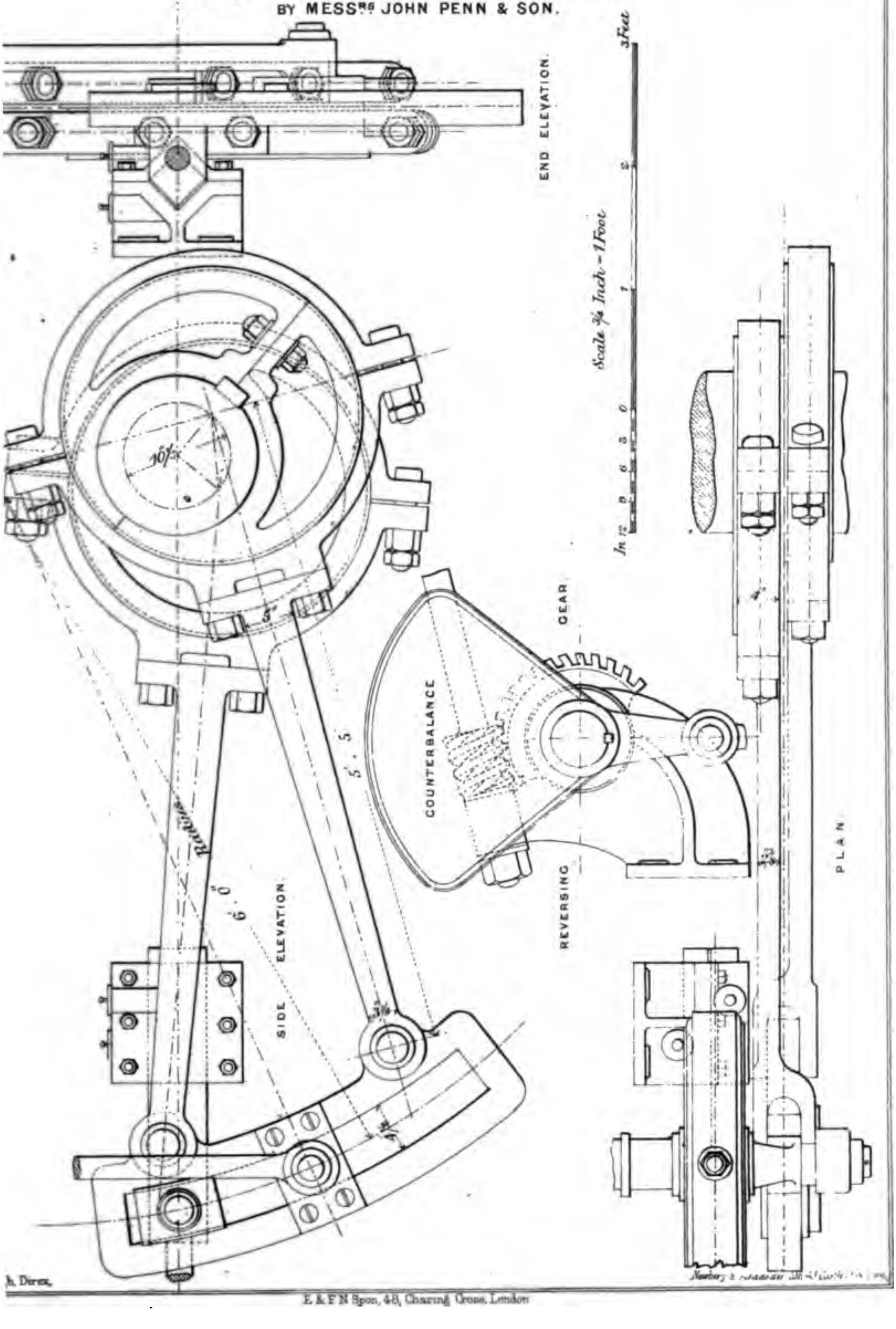
BY MESSRS JOHN PENN & SON.



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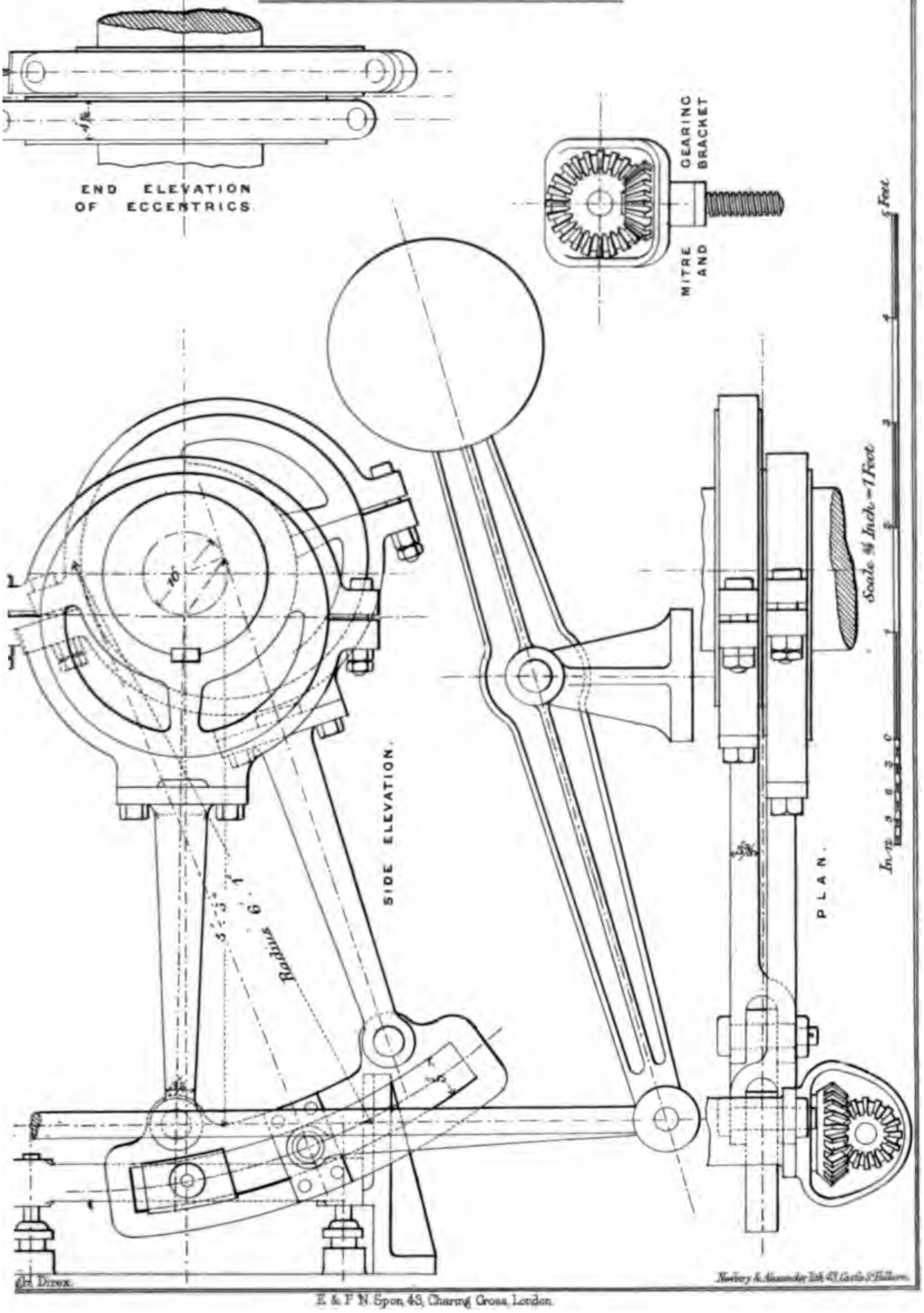
E & F N Spon, 48, Charing Cross, London

NK MOTION AND REVERSING GEAR, OF THE ENGINES FITTED IN H.M.S. "NORTHUMBERLAND" 1350 HP. No. COLLY

BY MESSRS. JOHN PENN & SON.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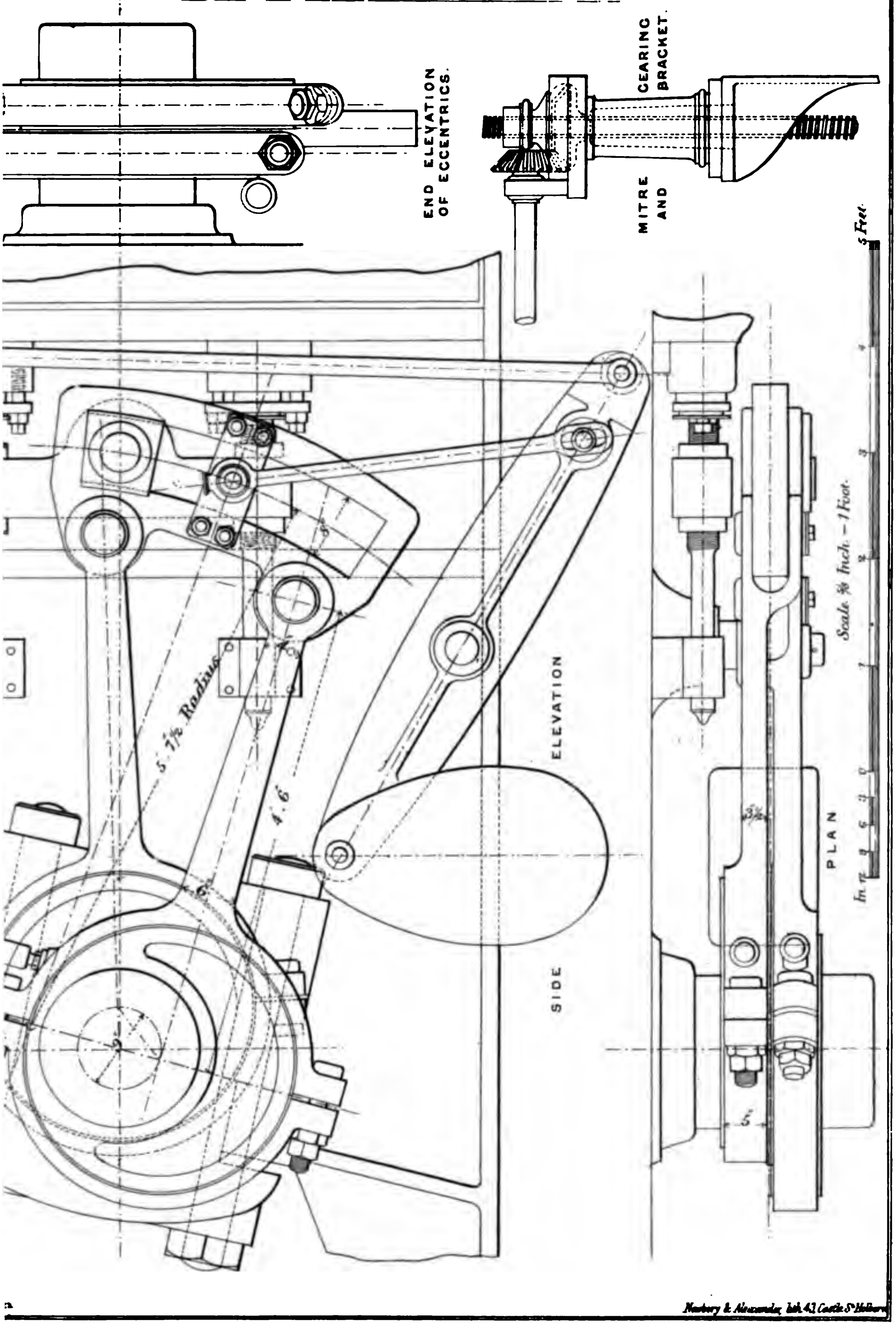
Scale ¾ Inch = 1 Foot
In. 12 9 6 3 0 1 2 3 4 5 Feet
Jn. Dirox
Newbery & Alexander, lith 43 Castle St Holborn.

E & F N Spon, 48, Charing Cross, London.

Plate 3

LINK MOTION AND PORTION OF REVERSING GEAR OF THE ENGINES
FITTED IN THE S.S. "ROMA" & "VENETIA" 900 H.P. NOML. COLLY.
BY MESSRS MAUDSLAY SONS & FIELD.

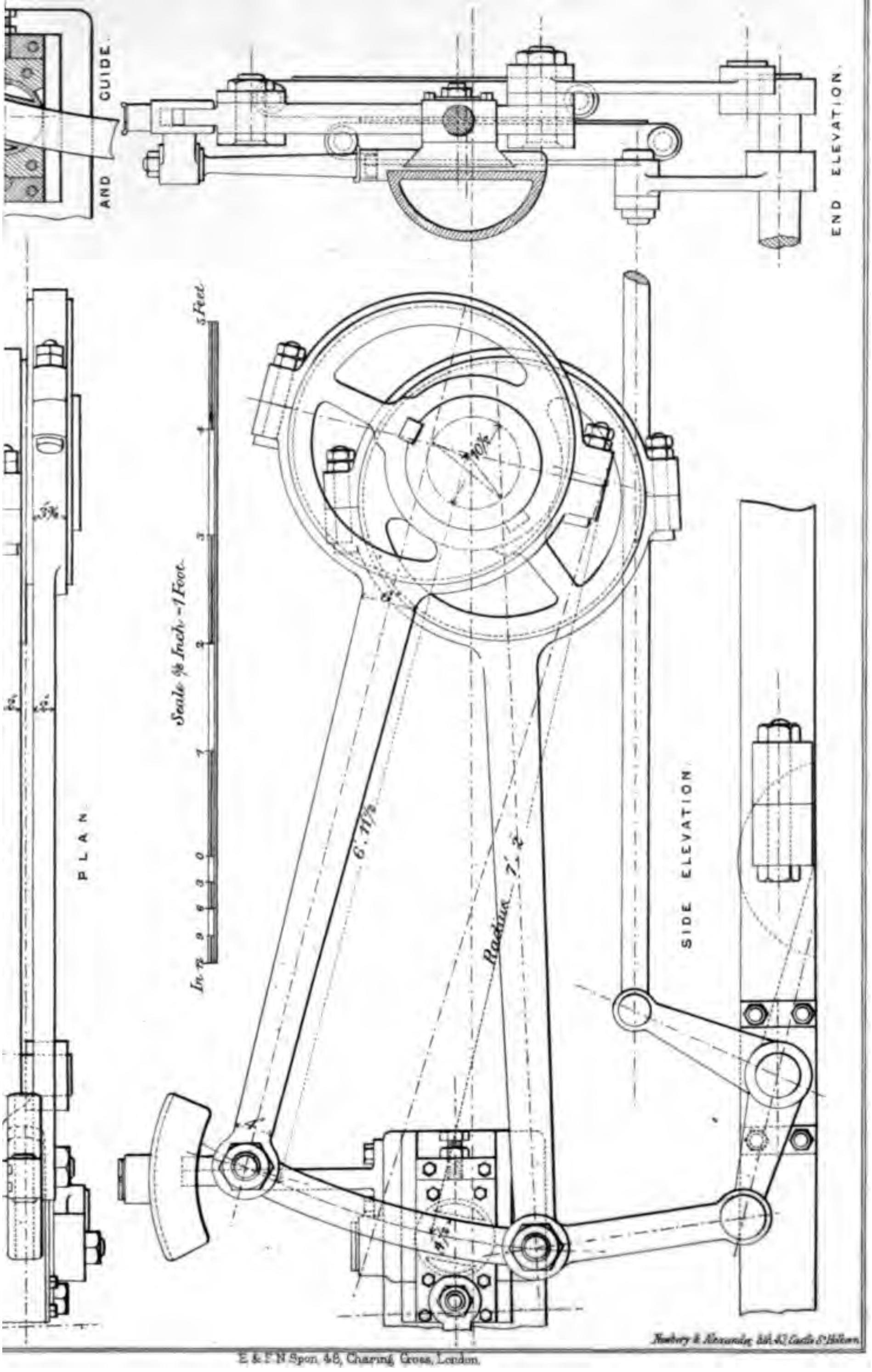

END ELEVATION OF ECCENTRICS.
MITRE AND GEARING BRACKET.
SIDE ELEVATION
PLAN
5' 1½ Radius
4' 6"
Scale ¾ Inch = 1 Foot.
In. 12 9 6 3 0 1 2 3 4 5 Feet

Newbery & Alexander, lith. 43 Castle St. Holborn

E & F N Spon, 48, Charing Cross, London

Plate 4

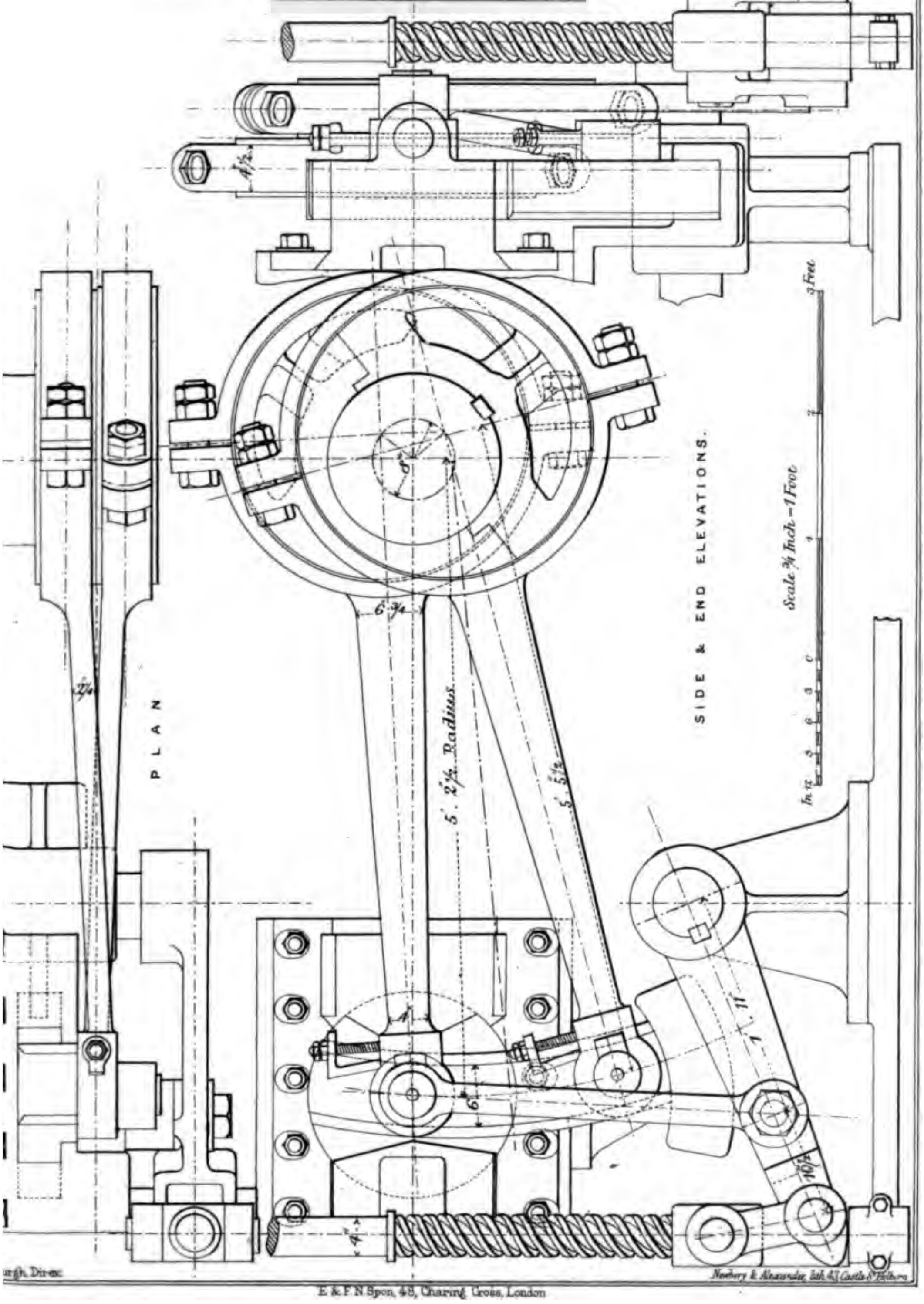
MOTION AND PORTION OF REVERSING GEAR, FITTED TO ENGINES 400 HP. NOML. COLLY BY MESSRS HUMPHRYS & TENNANT.



Newbery & Alexander, 38, 42, Castle St Holborn.

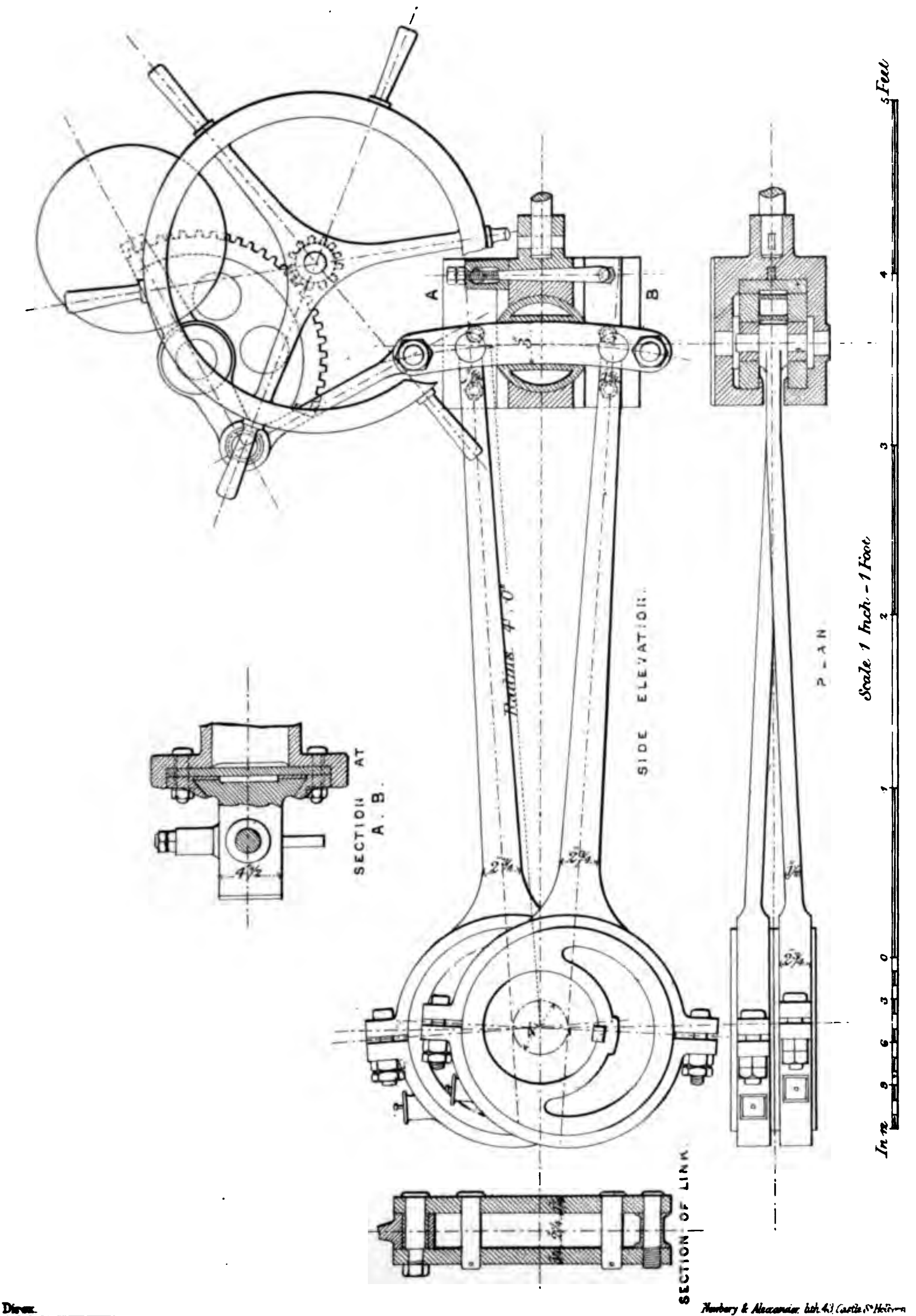
E. & F. N. Spon, 48, Charing Cross, London.

LINK MOTION AND PORTION OF REVERSING GEAR OF THE ENGINES
FITTED IN THE TURKISH FRIGATE "SULTAN MAHMOUD" 900 HP. NOML. COLLY
BY MESSRS RAVENHILL, HODGSON & CO



rgh. Direx
Newbery & Alexander, lith 43 Castle St Holborn
E & F N Spon, 48, Charing Cross, London

LINK MOTION AND REVERSING GEAR OF THE ENGINES FITTED IN H.M.S. "ENTERPRISE" 160, H.P. NOML. COLLY.
BY MESSRS RAVENHILL, HODGSON & Co.

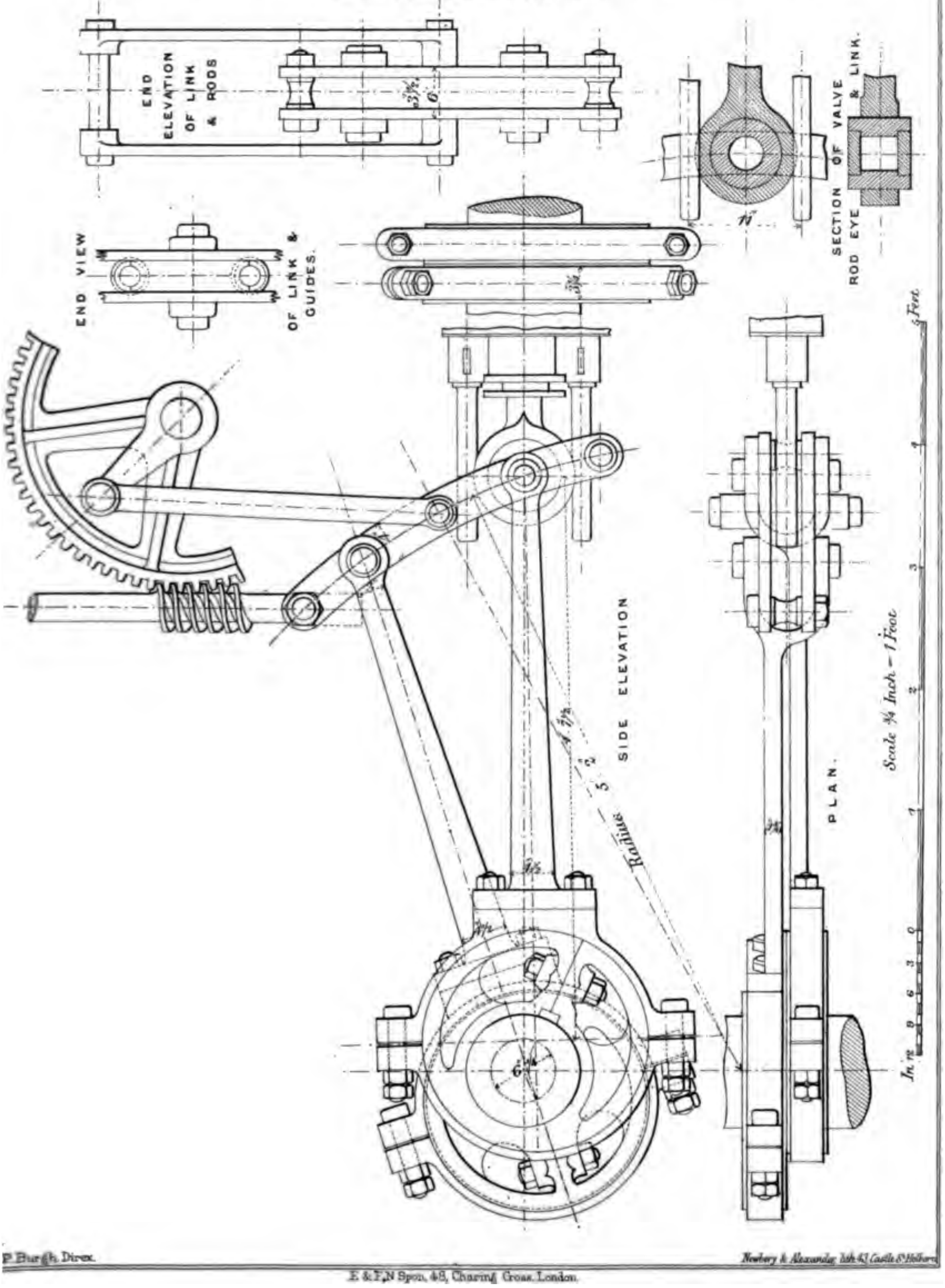


N.P. Burgh, Direx.

Newbery & Alexander lith. 43 Castle St Holborn

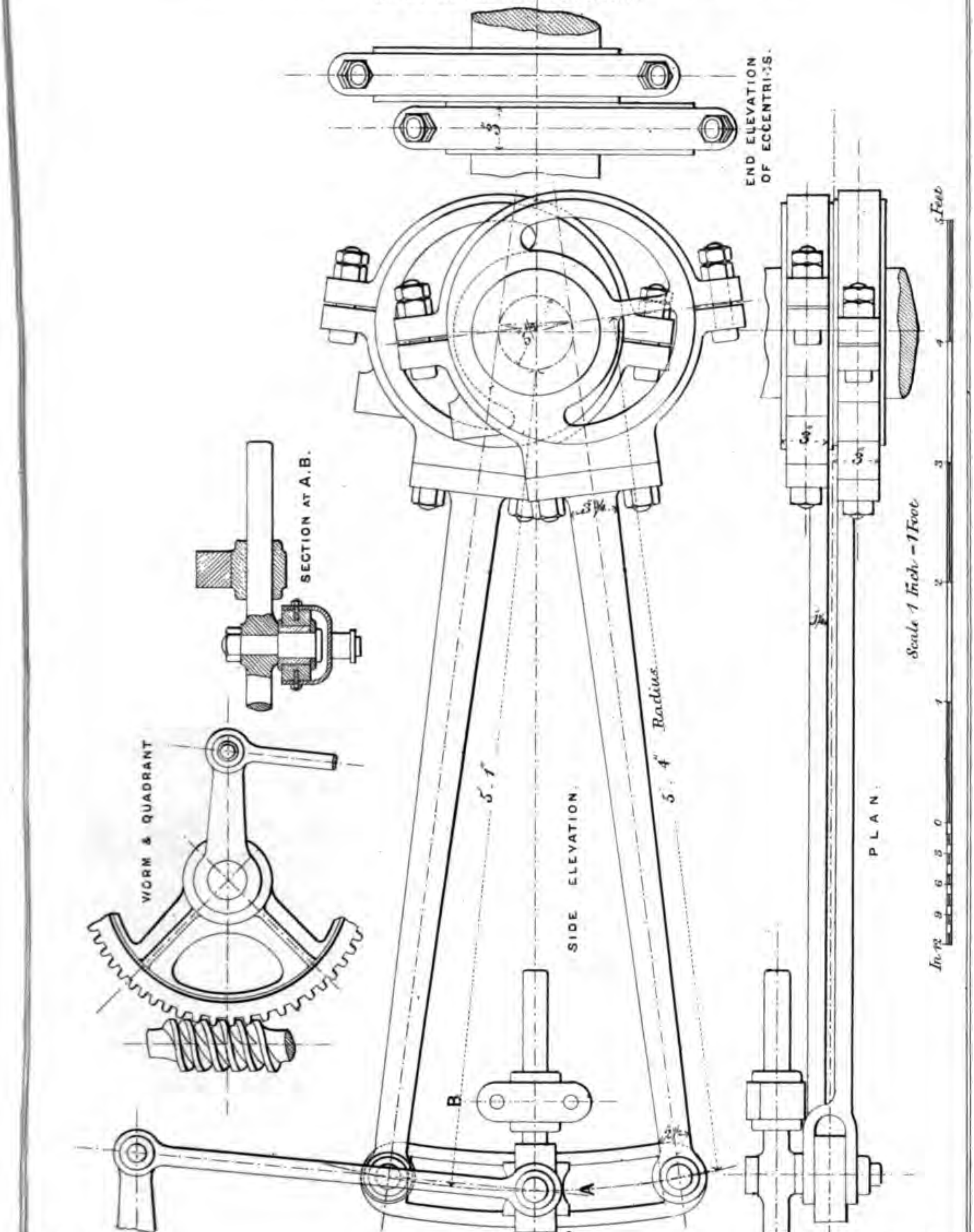
E. & F.N. Spon, 48, Charing Cross, London.

LINK MOTION AND REVERSING GEAR
FITTED IN THE ROYAL-MAIL S.S. "RUAHINE" TWIN SCREW ENGINES, 350 H.P. NOML COLLY
BY MESSRS J & W. DUDGEON.


END ELEVATION OF LINK & RODS
3½
6
SECTION OF VALVE ROD EYE & LINK
1½
END VIEW OF LINK & GUIDES
3¾
SIDE ELEVATION
4 7½
5 ½
Radius
1½
6¼
1½
PLAN
3¼
Scale ¾ Inch – 1 Foot
In. 12 9 6 3 0 1 2 3 4 5 Feet

P. Burgh. Direx.
Newbery & Alexander, lith. 43 Castle St. Holborn
E. & F. N. Spon, 48, Charing Cross, London.

LINK MOTION AND REVERSING GEAR.
FITTED IN THE S.S. "MARY AUGUSTA" TWIN SCREW ENGINES 300 H.P. NOML. COLLY
BY MESSRS. J & W. DUDGEON.



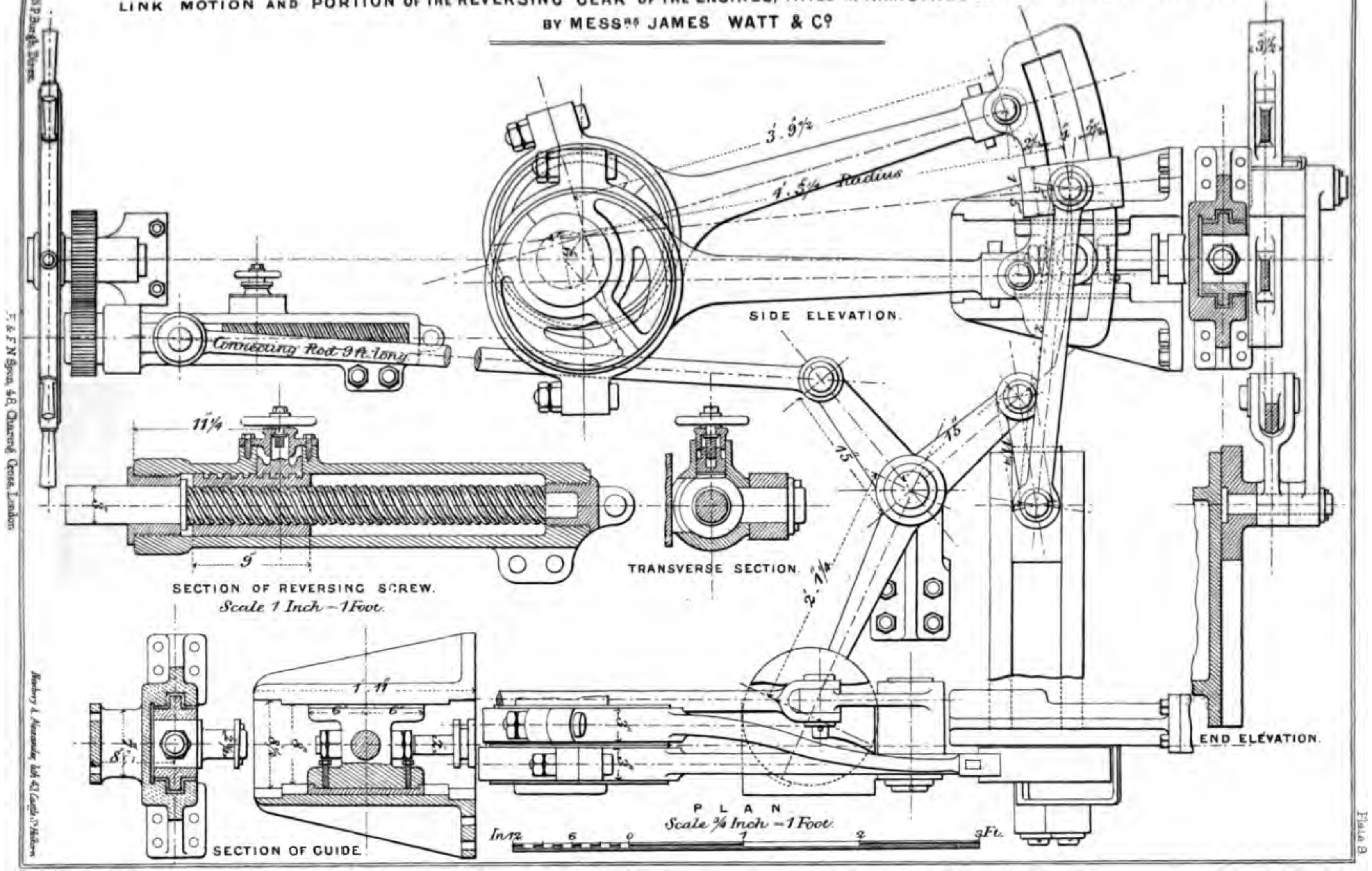
N. P. Burgh, Direx.

Newbery & Alexander, lith. 43 Castle St. Holborn.

E. & F. N. Spon, 48, Charing Cross, London.

LINK MOTION AND PORTION OF THE REVERSING GEAR OF THE ENGINES, FITTED IN H.M.S. "RESEARCH" 200 HP. NOML. COLLY

BY MESSRS. JAMES WATT & Co.

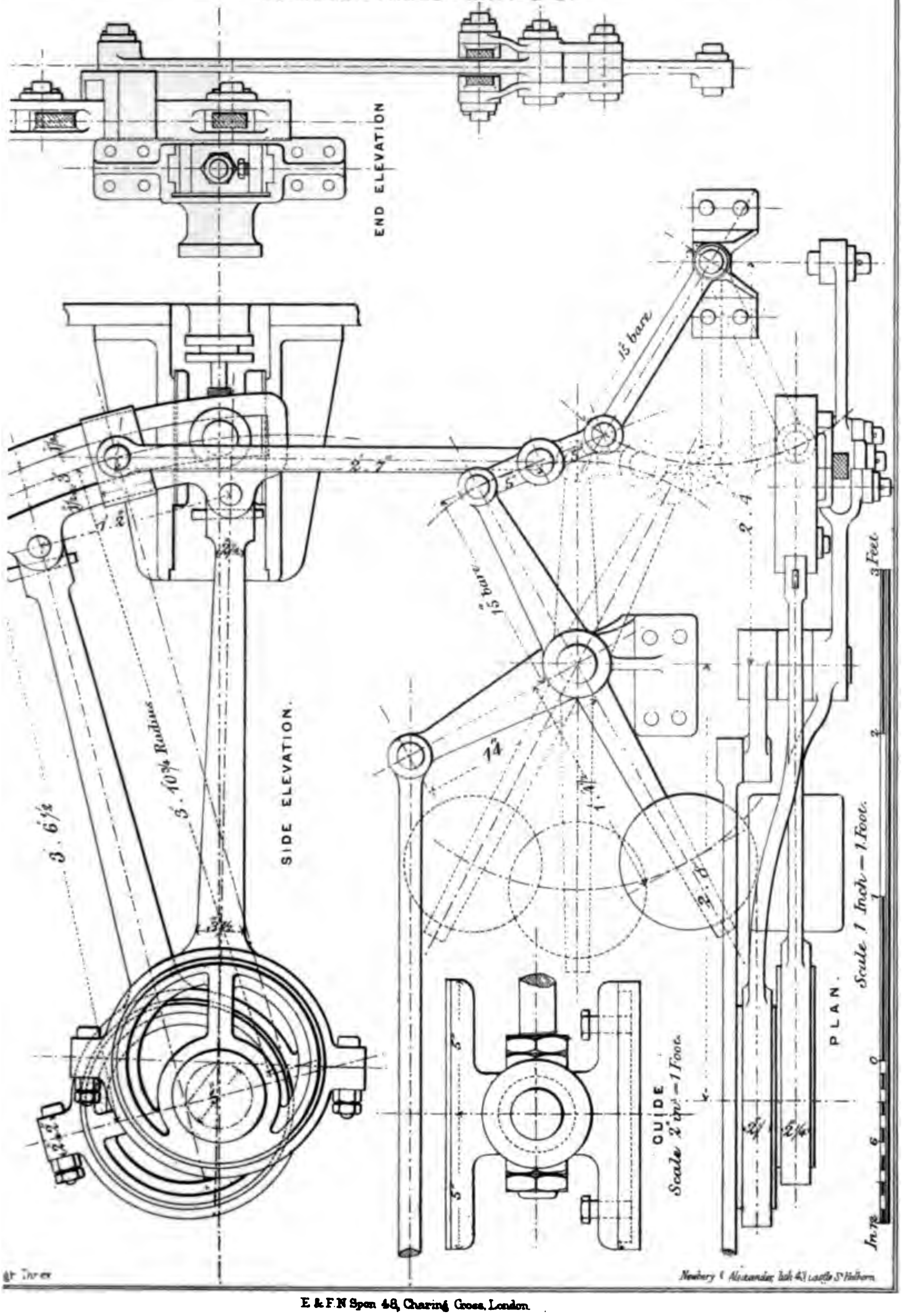


N. P. Burgh Direx.

E. & F. N. Spon, 48, Charing Cross, London.

Newbery & Alexander, lith 43 Castle St Holborn

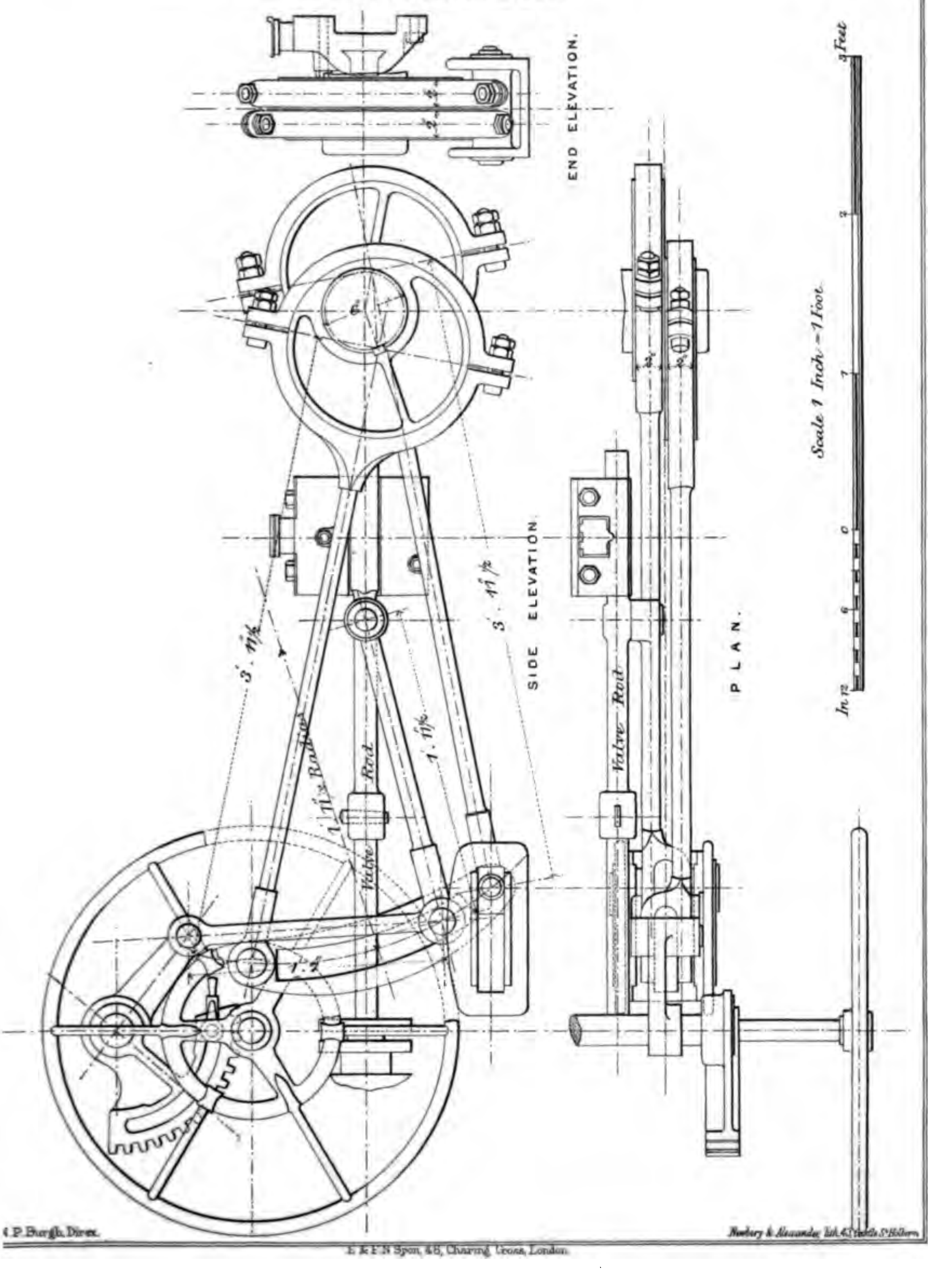
LINK MOTION AND PORTION OF REVERSING GEAR,
FITTED IN S. S. "MÆDUSA" AND "TRITON". TWIN SCREW ENGINES, 200 HP. NOML. COLLY.
BY MESSRS. JAMES WATT & CO.



Newbery & Alexander, lith 43 Castle St Holborn

E. & F. N. Spon 48, Charing Cross, London.

LINK MOTION AND REVERSING GEAR OF THE ENGINES, 70 HP. NOML. COLLY
BY R. NAPIER & SON.

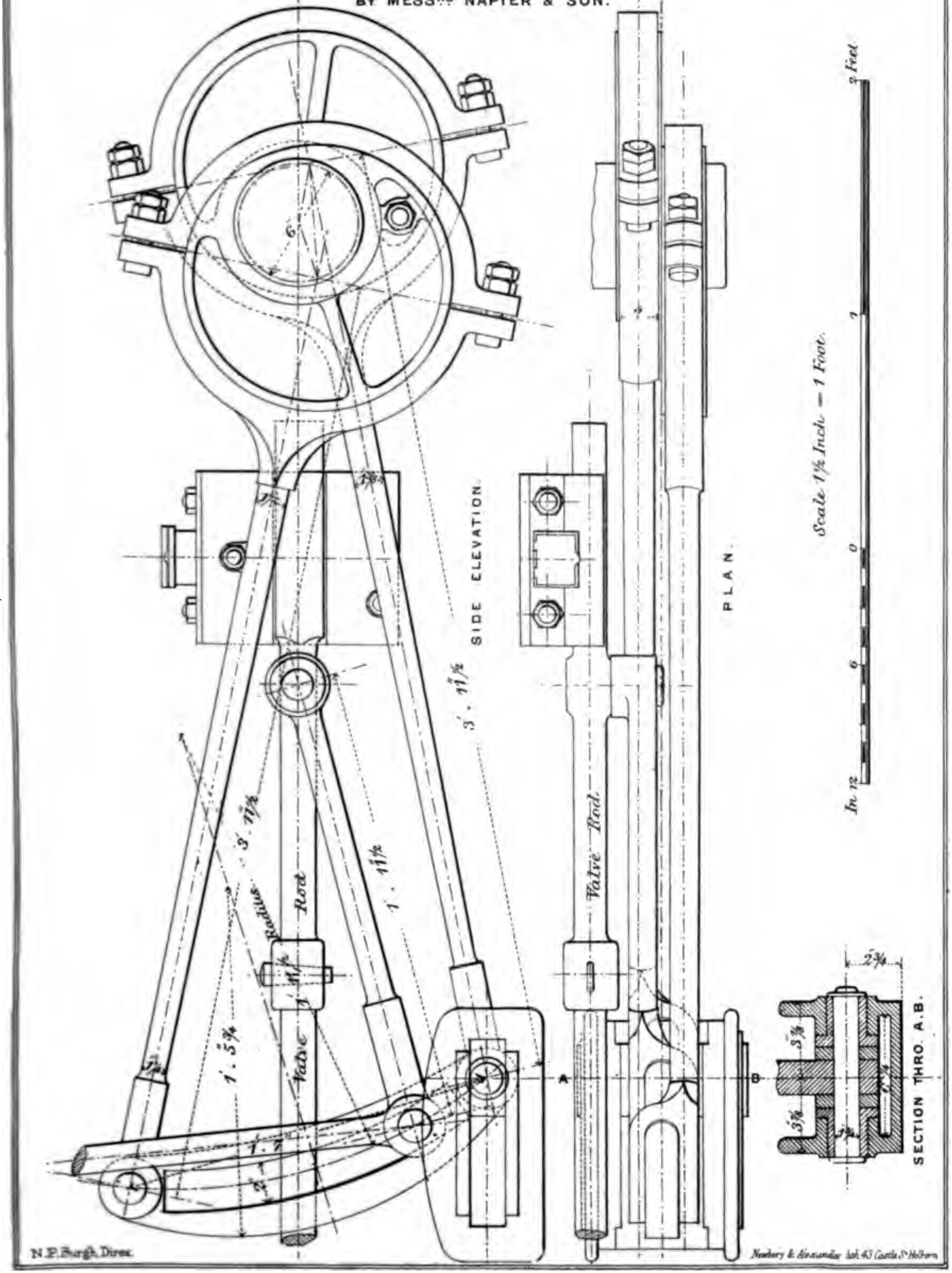


A. P. Burgh, Direx.

Newbery & Alexander, lith. 43 Castle St. Holborn

E & F N Spon, 48, Charing Cross, London.

LINK MOTION OF THE ENGINES 70 HP. NOML. COLLY
BY MESSRS. NAPIER & SON.

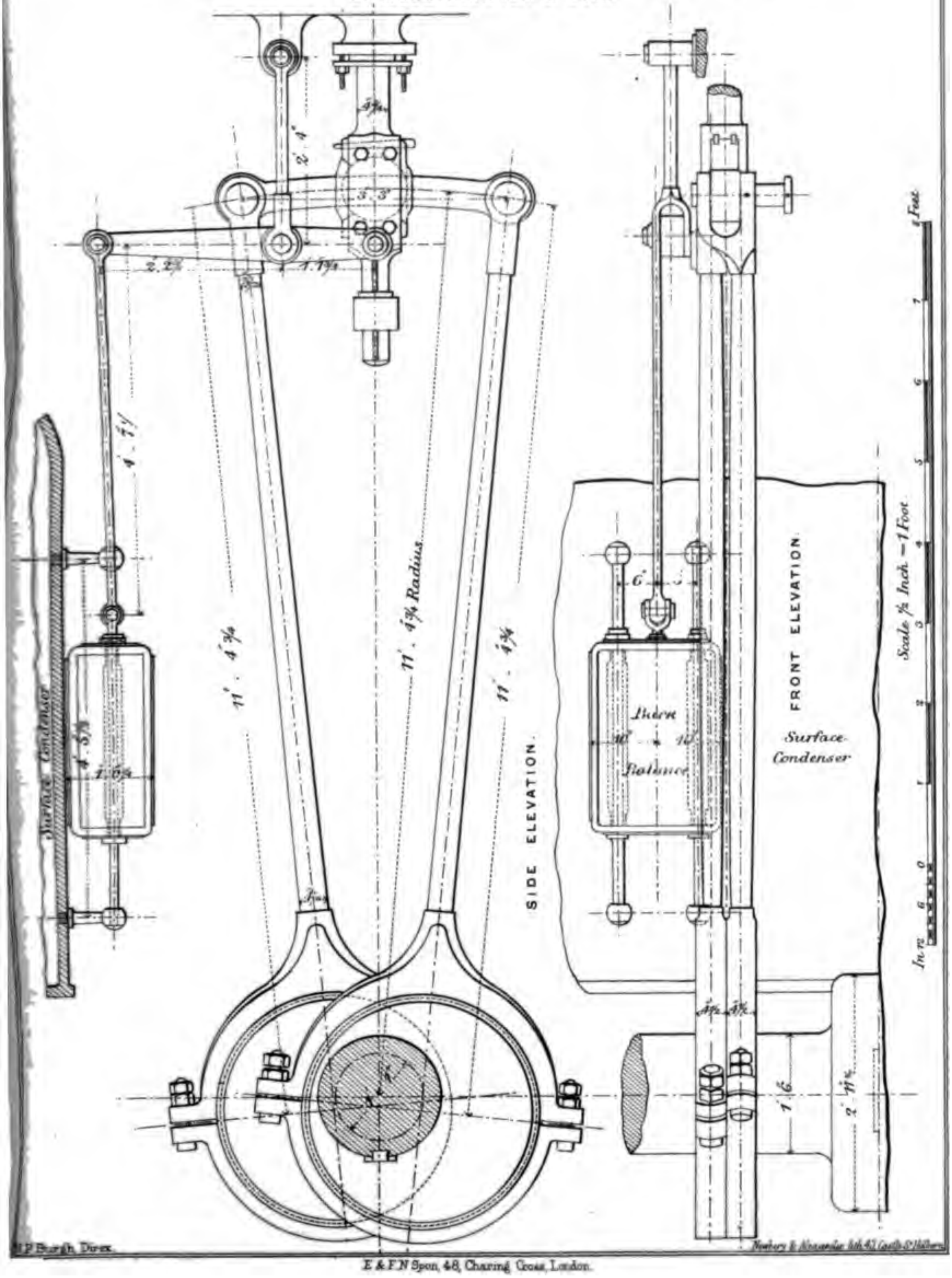


N. P. Burgh, Direx.

Newbery & Alexander lith. 43 Castle St. Holborn

E & F N Spon, 48 Charing Cross, London

LINK MOTION AND BACK BALANCE, OF THE ENGINES, FITTED IN S.S. "PERIERE" AND "VILLE DE PARIS" 800 HP. NOML. COLLY BY MESSRS NAPIER & SON.

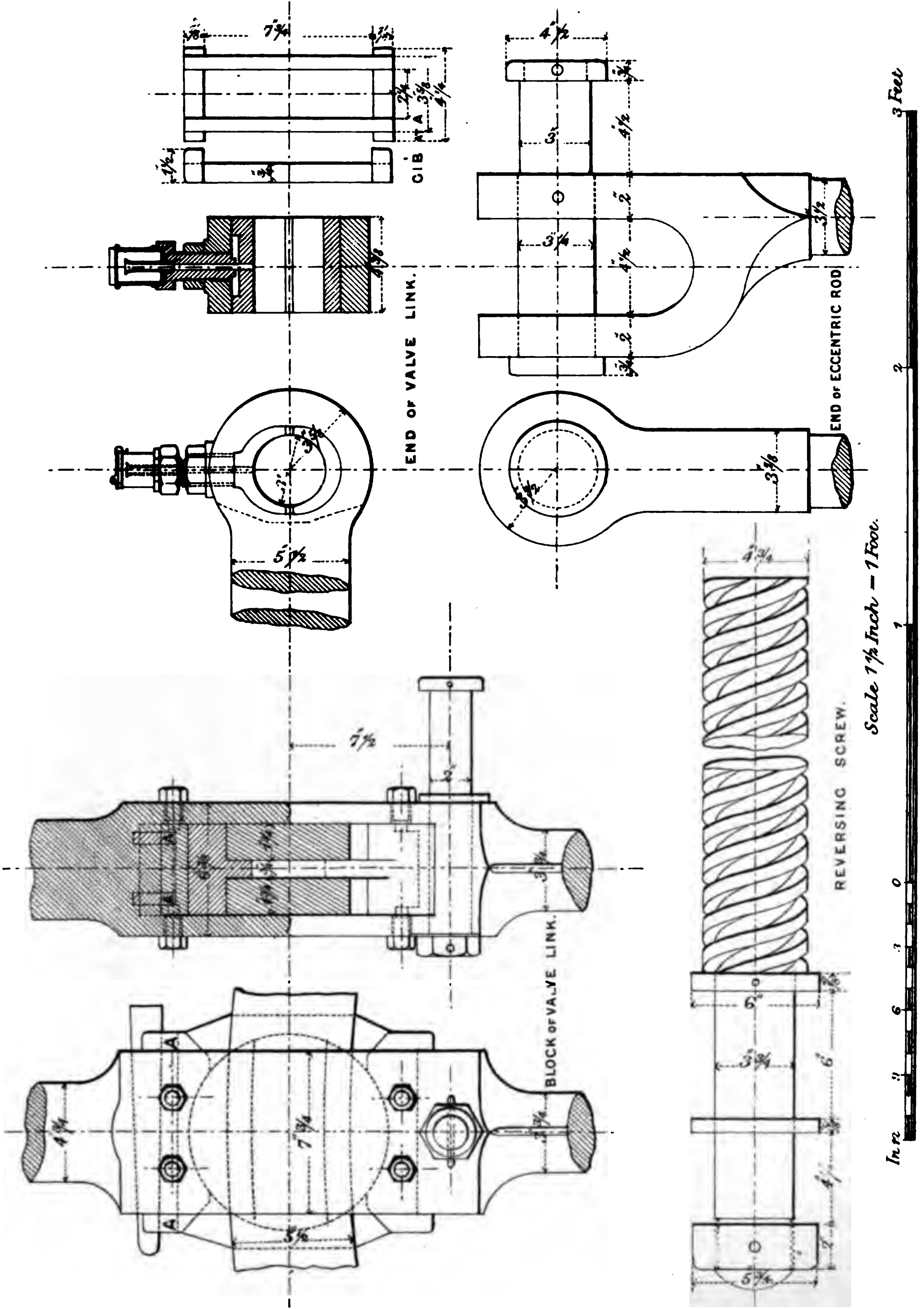


N.P. Burgh, Direx.

Newbery & Alexander lith 42 Castle St Holborn

E & F.N Spon, 48, Charing Cross, London.

MAIN DETAILS OF THE LINK MOTION OF THE ENGINES
FITTED IN S.S.S "PERIERE" AND "VILLE DE PARIS" 800 H.P. NOML. COLLY
BY MESSRS NAPIER & SON.

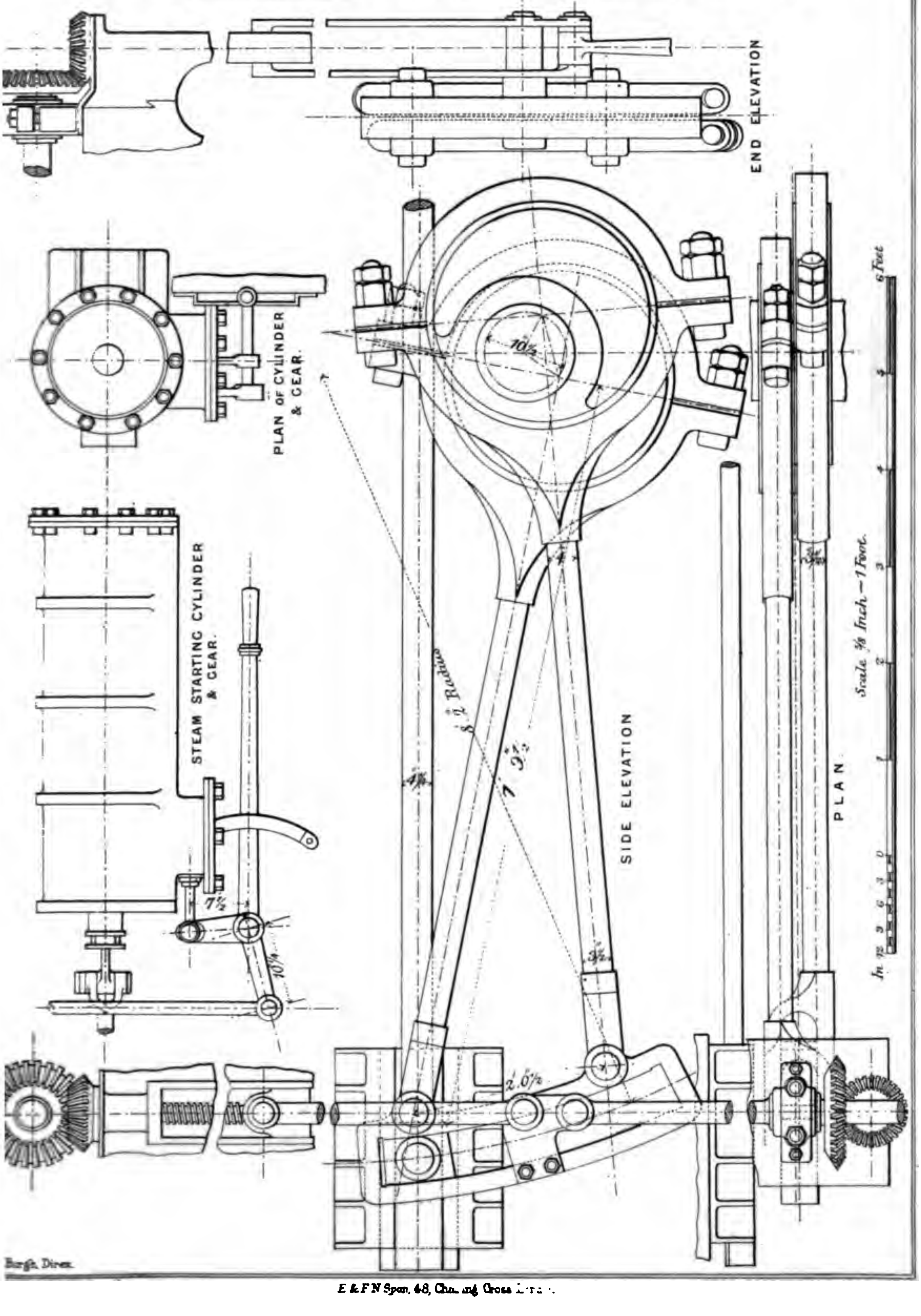


. Direx.

Newbery & Alexander, lith 4 Castle St Holborn

E & F N Spon, 48, Charing Cross, London.

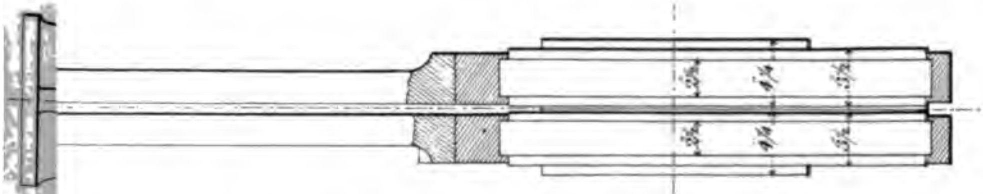
LINK MOTION & PORTION OF THE STEAM & HAND REVERSING-GEAR OF THE ENGINES. FITTED IN H.M.S."HECTOR", 800 HP., NOML., COLLY., BY MESSRS R. NAPIER & SON.

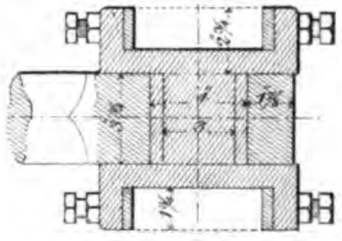


Burgh, Direx.

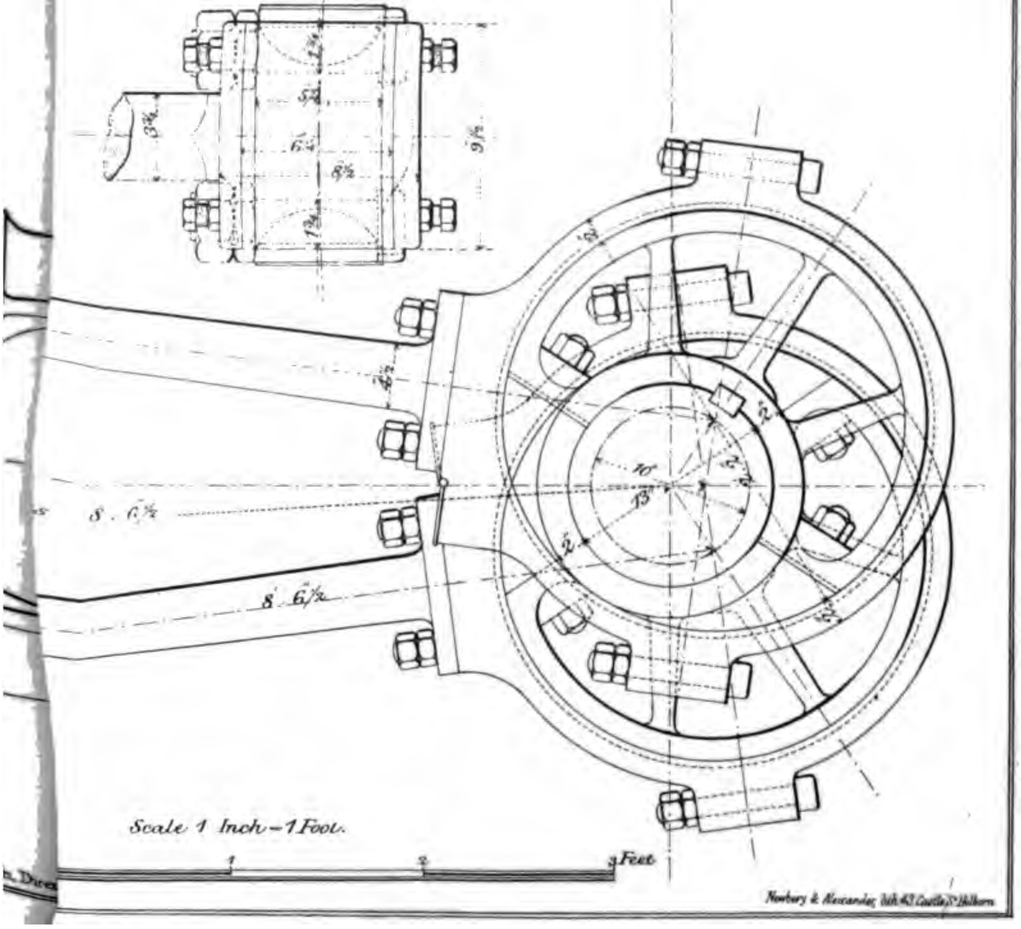
E & F N Spon, 48, Charing Cross London.

ENGINES, 250 HP. NOML COLLY
AD.





DETAIL OF LINK BLOCK
Scale 1½ Inch – 1 Foot.

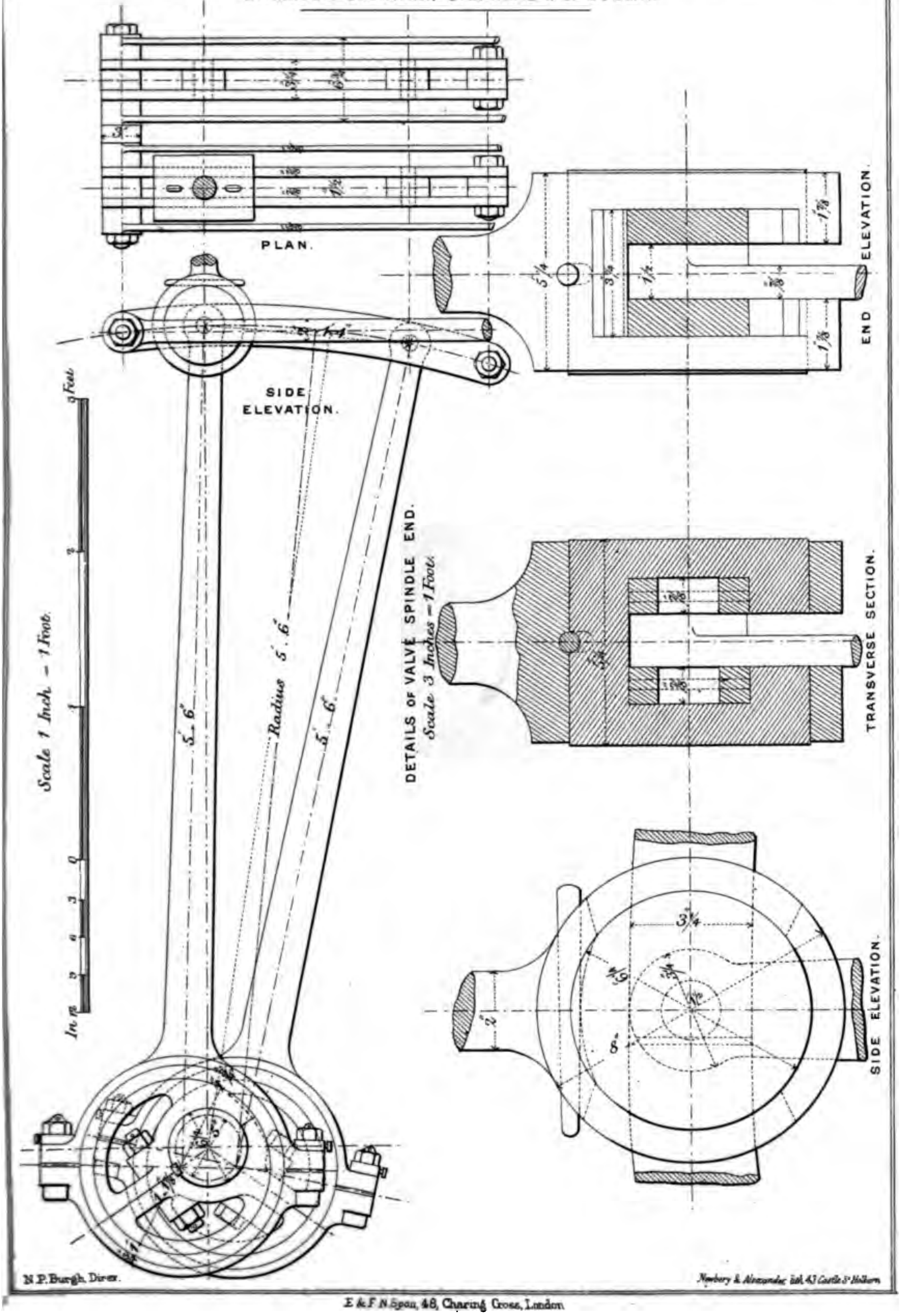


Scale 1 Inch – 1 Foot.

Newbury & Alexander, lith 43 Castle St. Holborn

Plate 19.

LINK MOTION OF THE ENGINES. FITTED IN S.S. "DUBLIN." 70 HP. COLLY
BY MESSRS COURTNEY, STEPHENS & Co DUBLIN.



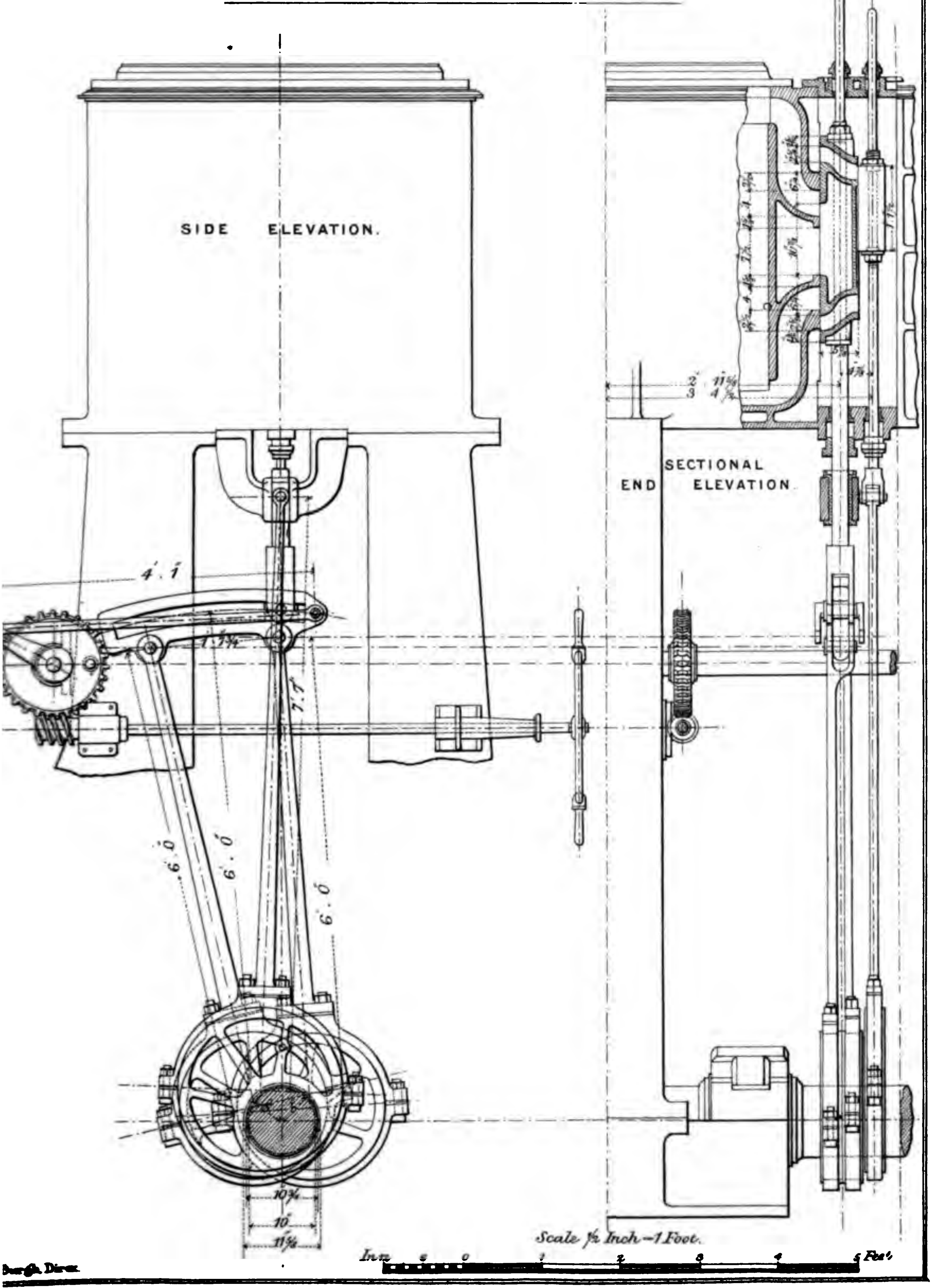
N.P. Burgh, Direx.

Newbery & Alexander, lith. 43 Castle St Holborn

E & F N Spon, 48, Charing Cross, London

ARRANGEMENT OF LINK MOTION & EXPANSION GEAR FOR ENGINES OF 160 HP. AS FITTED FOR THE R.S.N.C^o

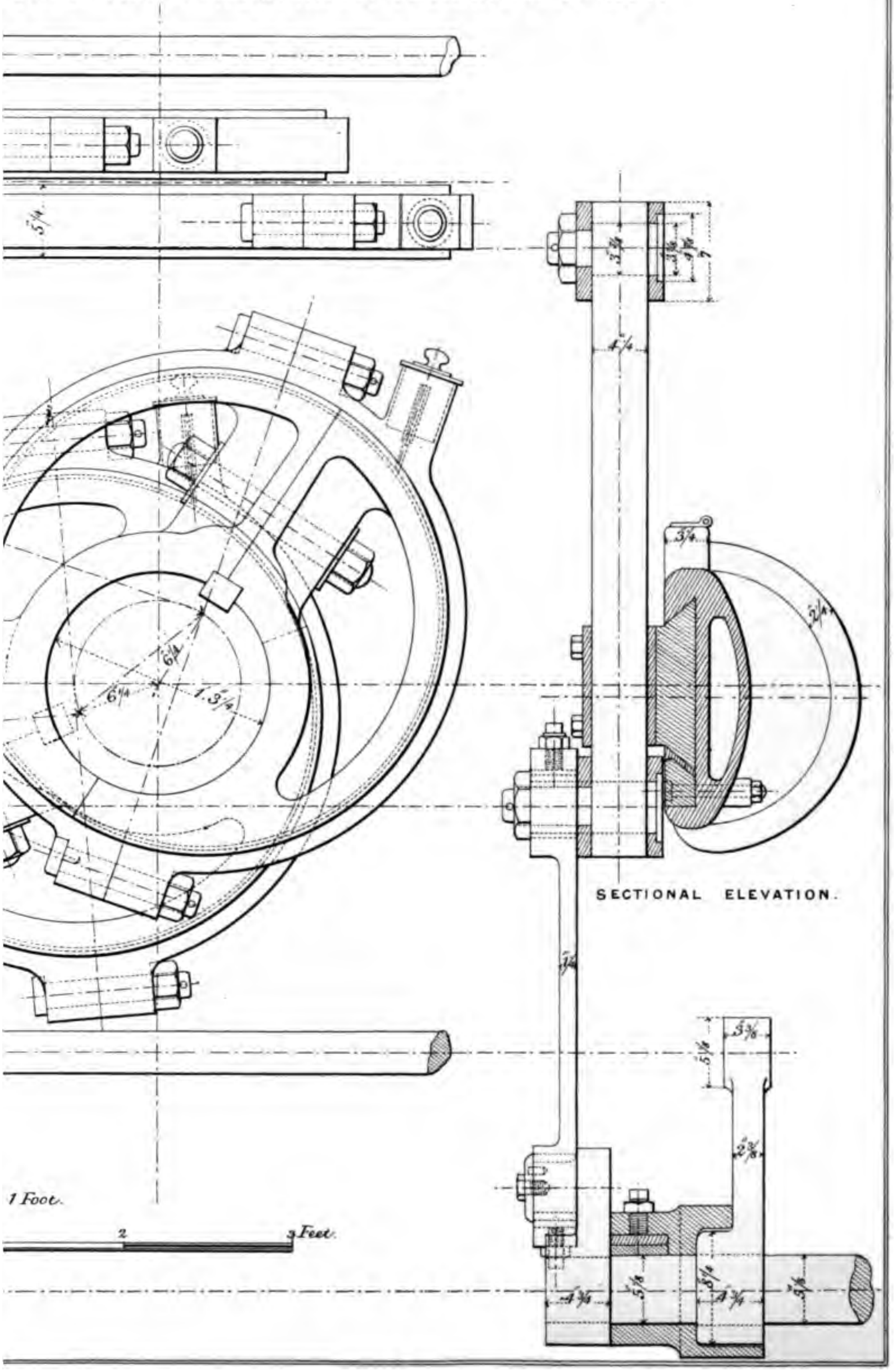
BY MESS^{RS} J. PENN & SON.



Burgh. Direx.

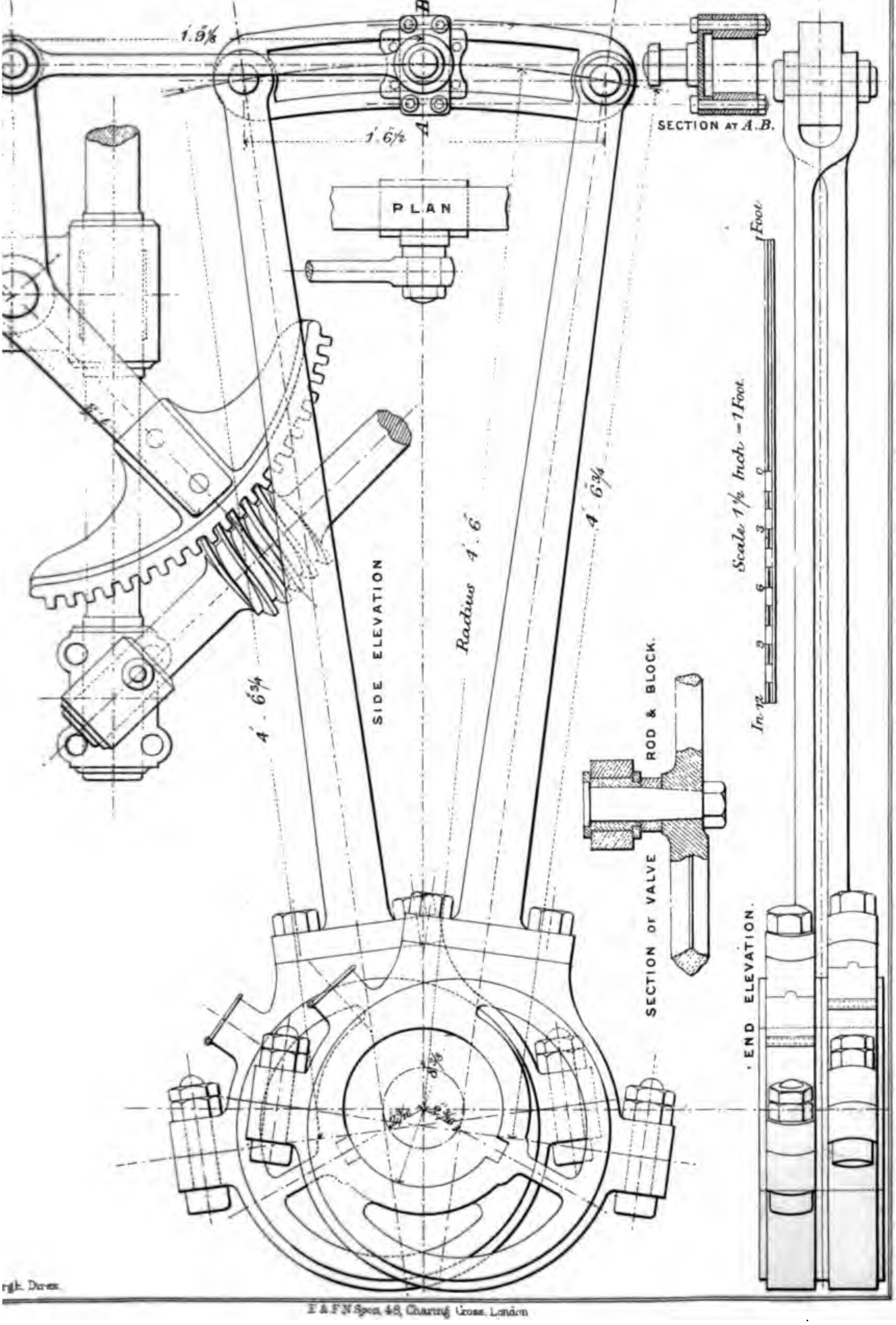
E & F N Spon, 48, Charing Cross, London

ION BY MESSRS HUMPHRYS, TENNANT & Co 1870.



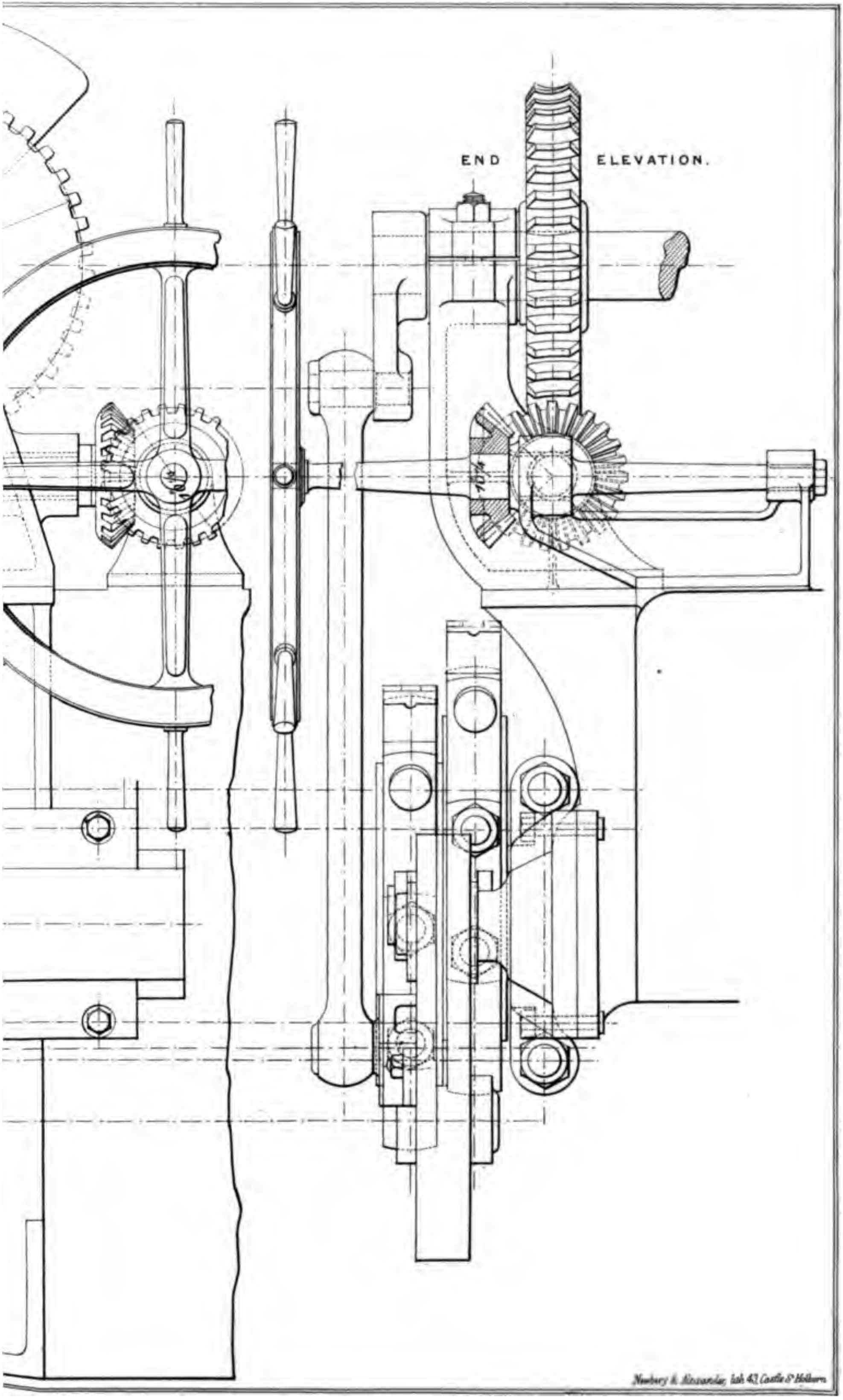
SECTIONAL ELEVATION.

LINK MOTION & REVERSING GEAR.
FITTED IN H.M.S. "ABYSSINIA" TWIN SCREW ENGINES. 200 HP. NOML. COLLY
BY MESSRS. J & W. DUDGEON.



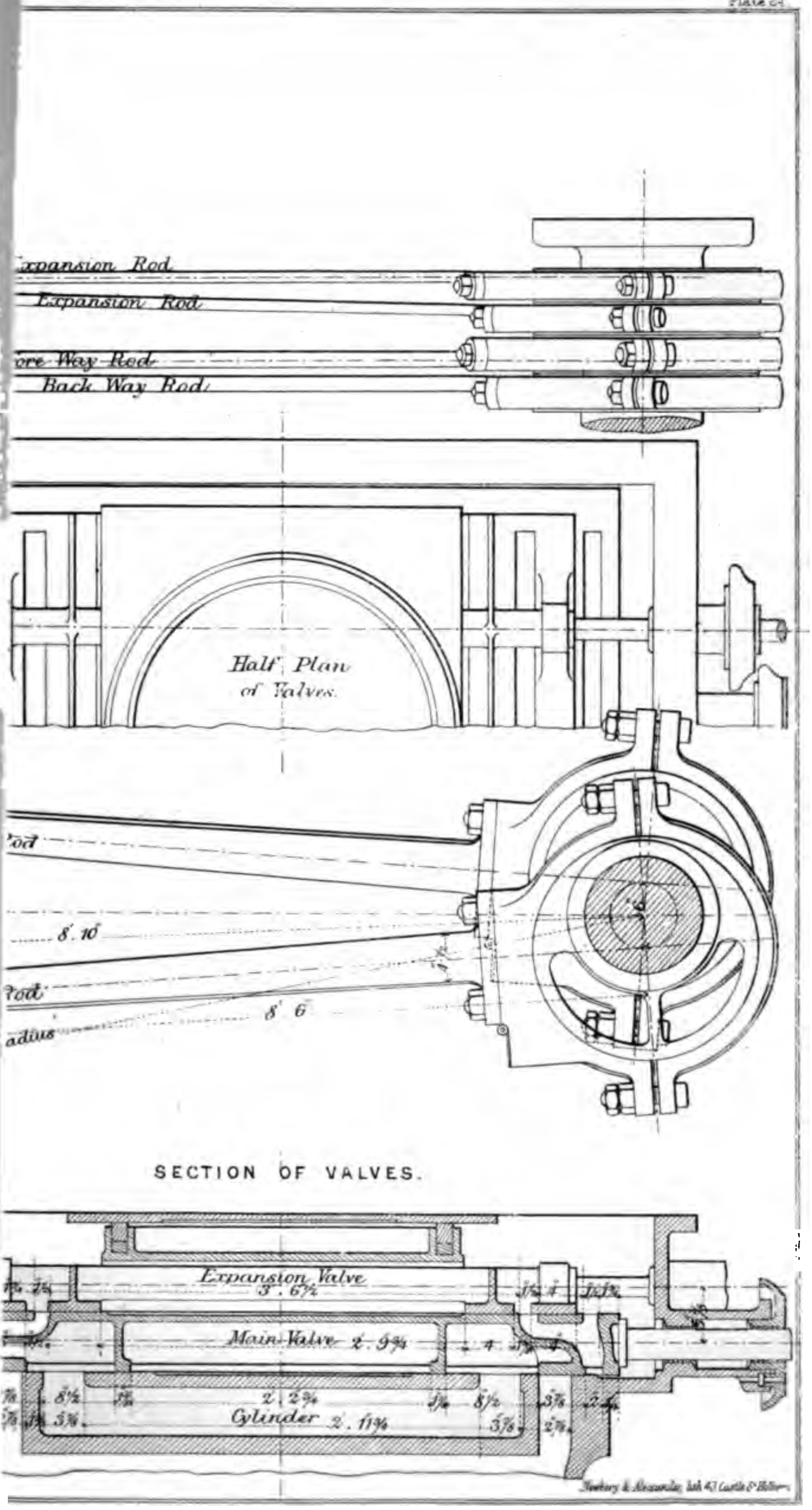
rgh. Dunes.

E & F N Spon, 48, Charing Cross, London



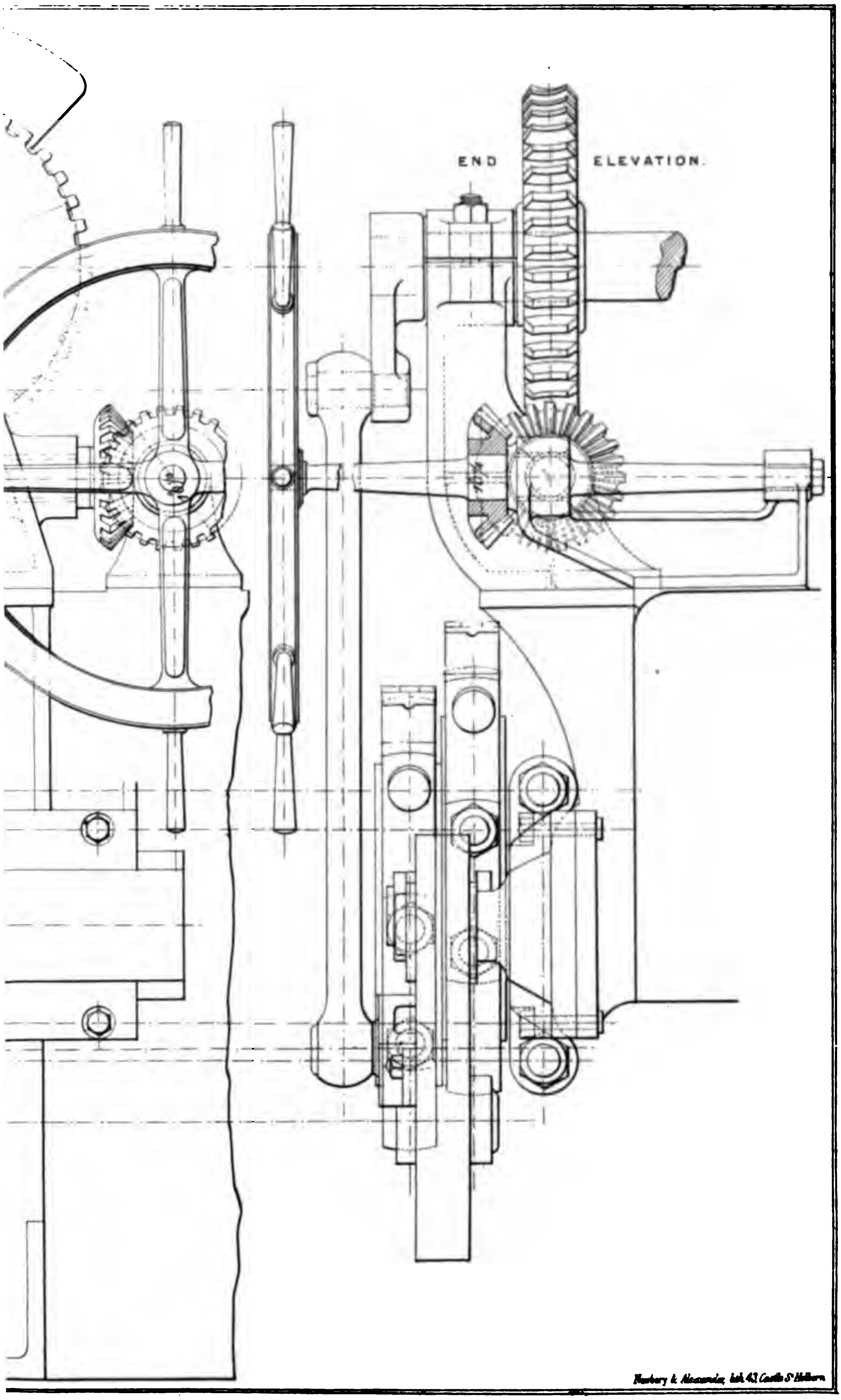
Newbery & Alexander, lith 43 Castle St Holborn

Plate 24



Newbury & Alexander, lith 43 Castle St Holborn

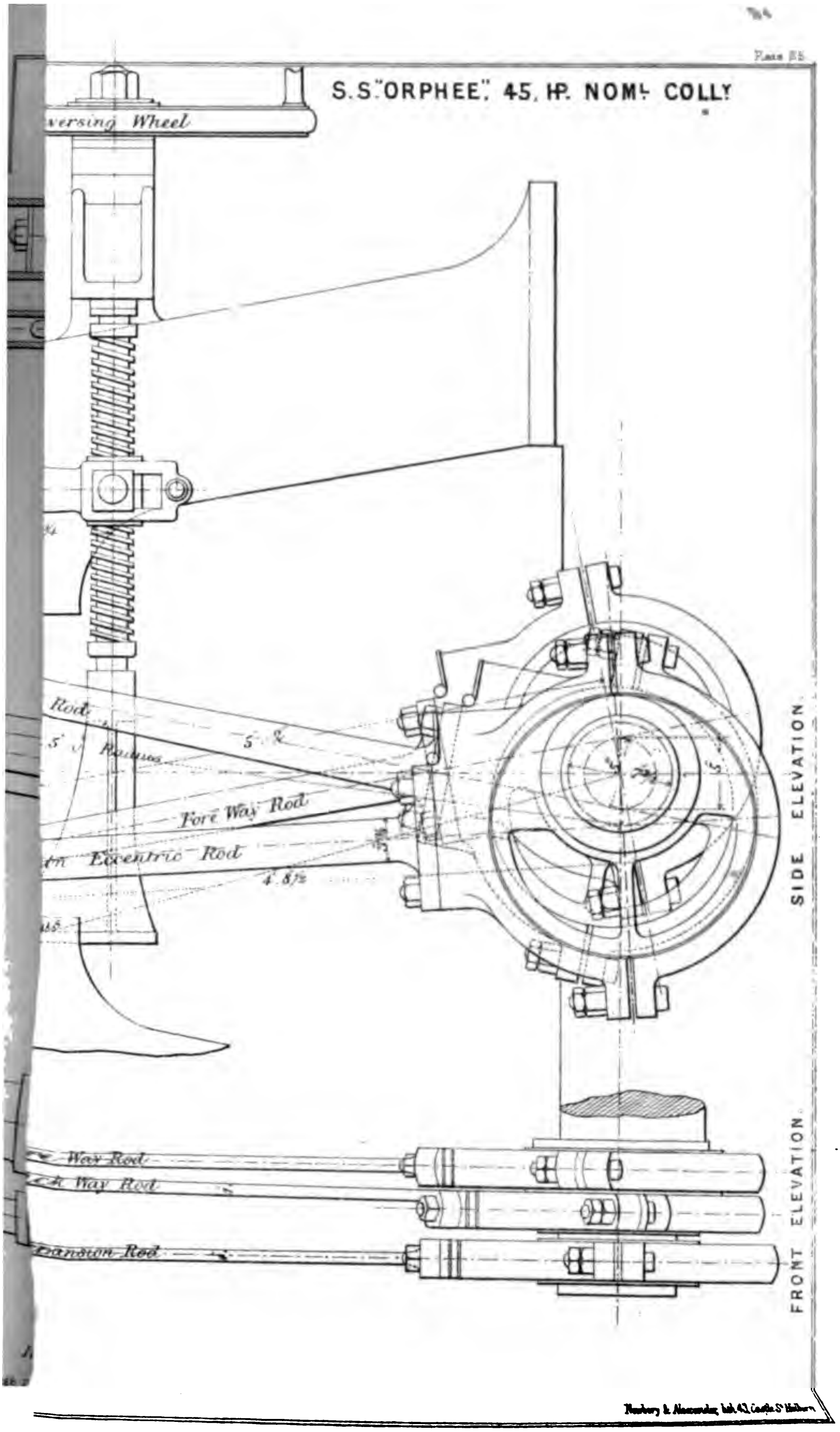
Plate 23



Newbery & Alexander, lith 43 Castle S^t Holborn

Plate 85.

S.S. "ORPHEE." 45. HP. NOML. COLLY.



Newbery & Alexander, lith. 42 Castle St Holborn

LINK MO XPANSION GEAR, OF THE ENGINES, FITTED IN W. I. M. S. "COLUMBIAN." 300 HP. NOML. COLLY.

BY G. W. JAFFREY, FOR THOS RICHARDSON & SONS.

Scale ¾ Inch = 1 Foot.

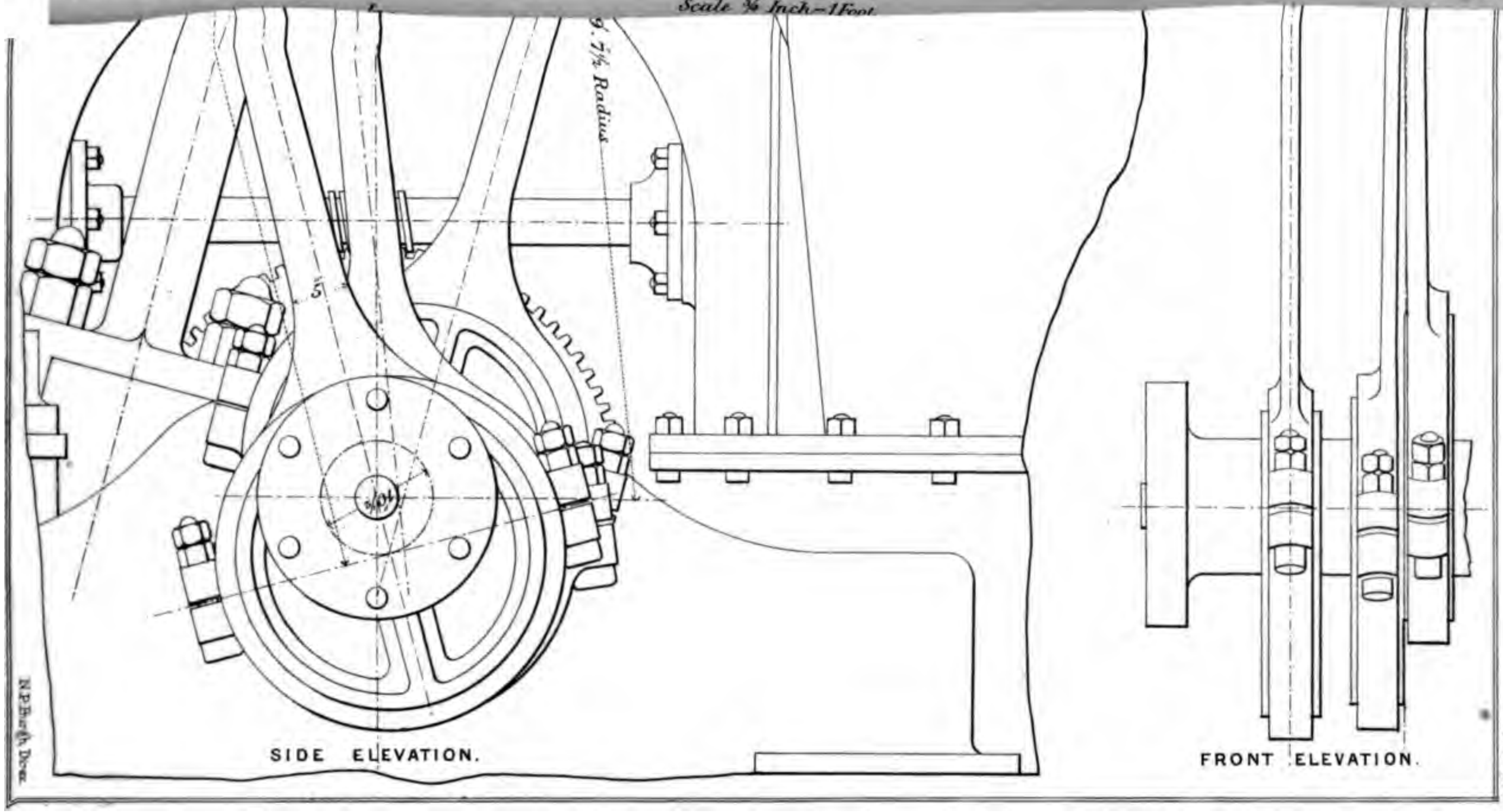
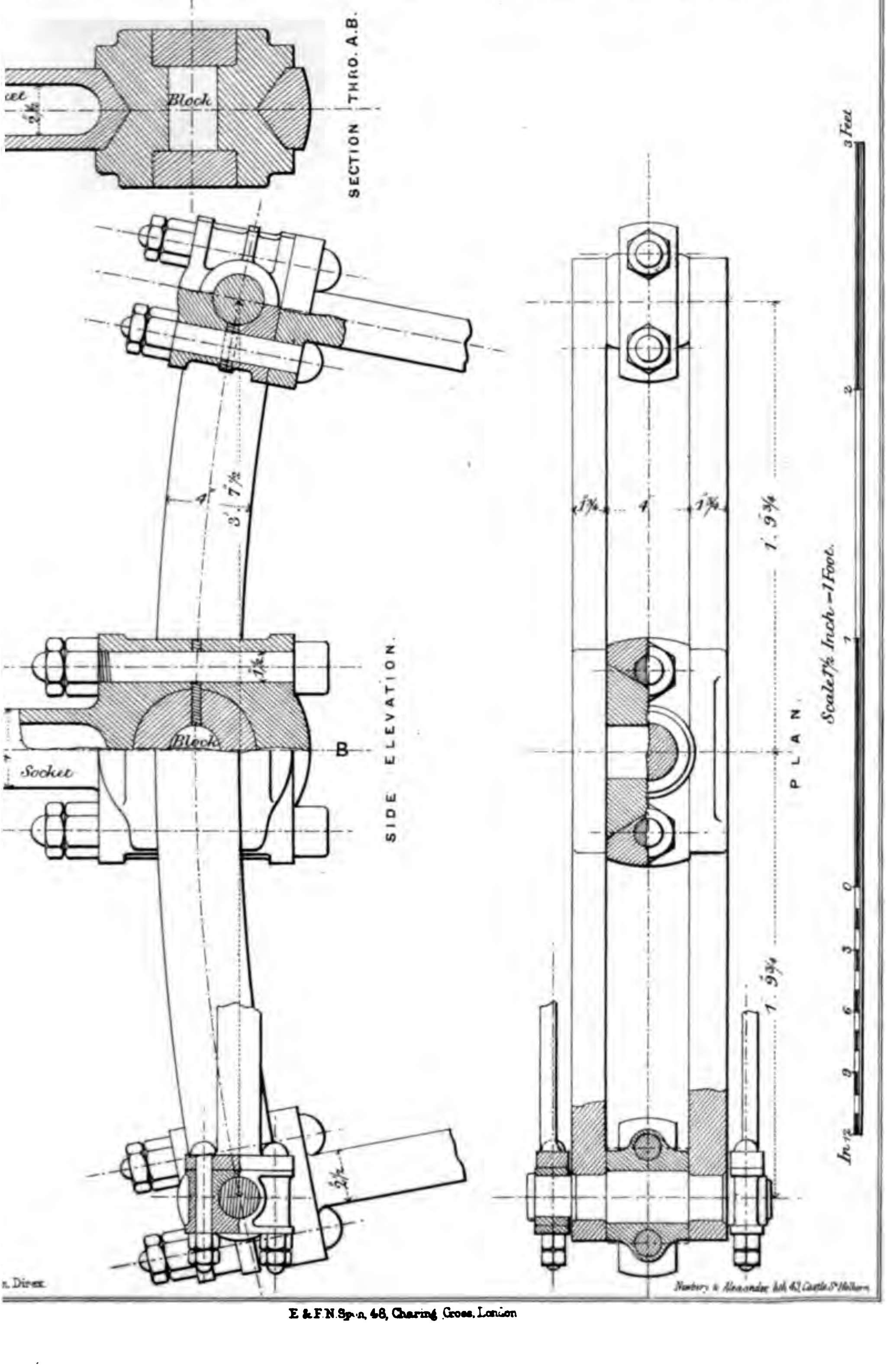


Plate 27

DJUSTABLE LINK, AND CONNECTIONS OF THE ENGINES, FITTED IN W. I. M. S. "COLUMBIAN."

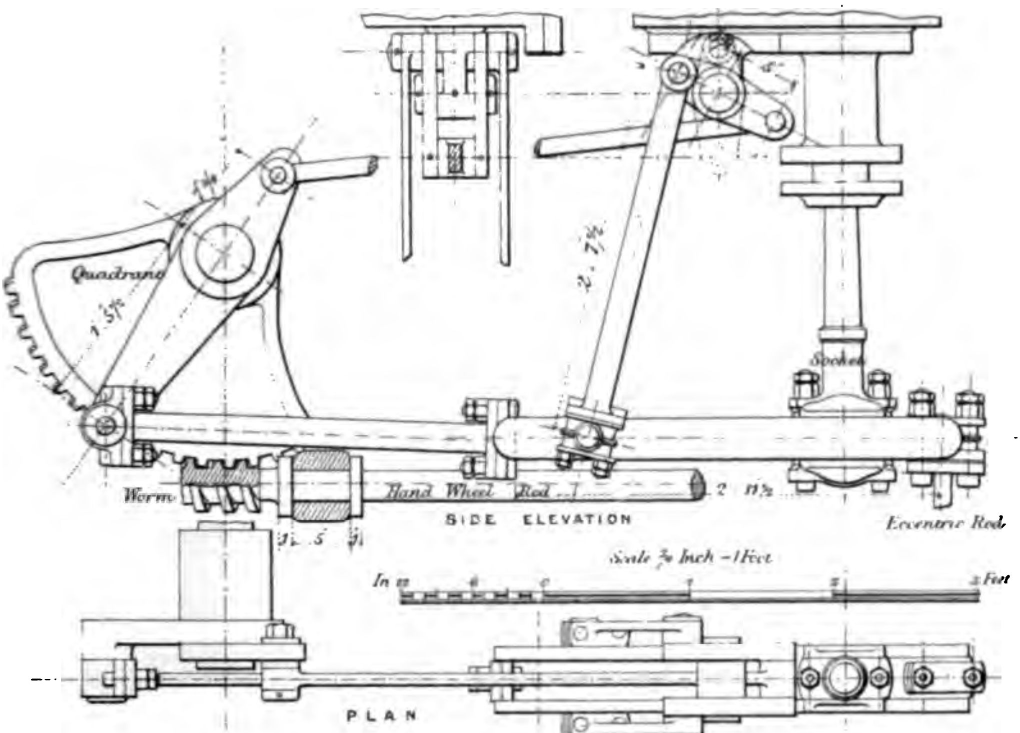


n. Direx

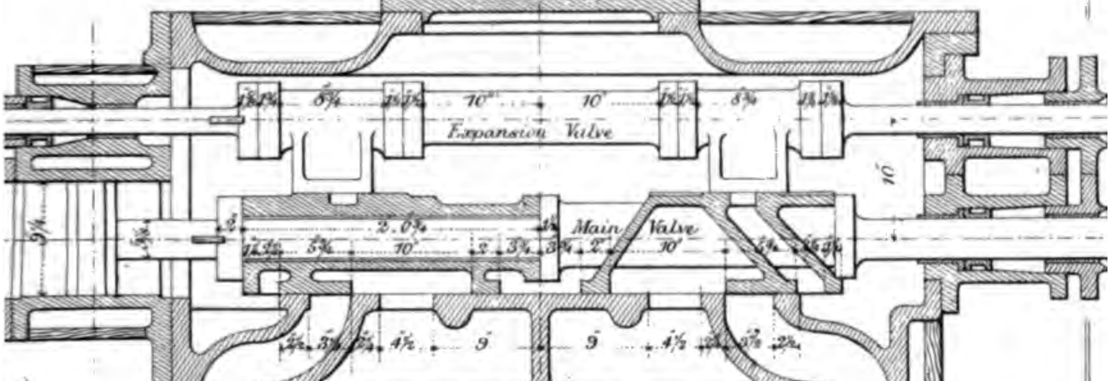
Newbery & Alexander lith 42 Castle St Holborn

E & F N Spon, 48, Charing Cross, London

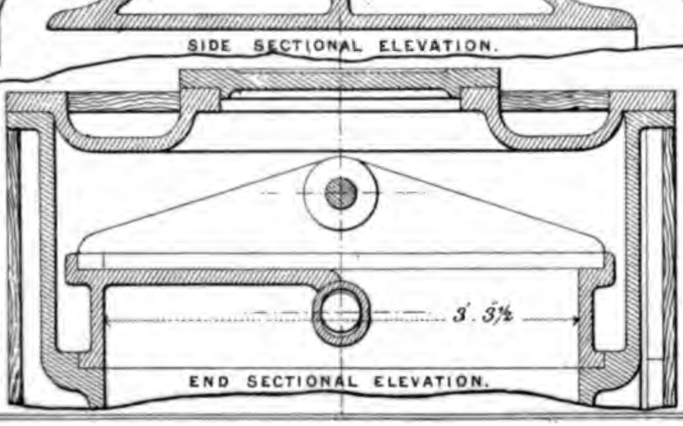
AN ARRANGEMENT OF EXPANSION GEAR, BY MR C. W. JAFFREY.



SLIDE VALVES OF THE ENGINES FITTED IN W M.S. "COLUMBIAN."



SIDE SECTIONAL ELEVATION.



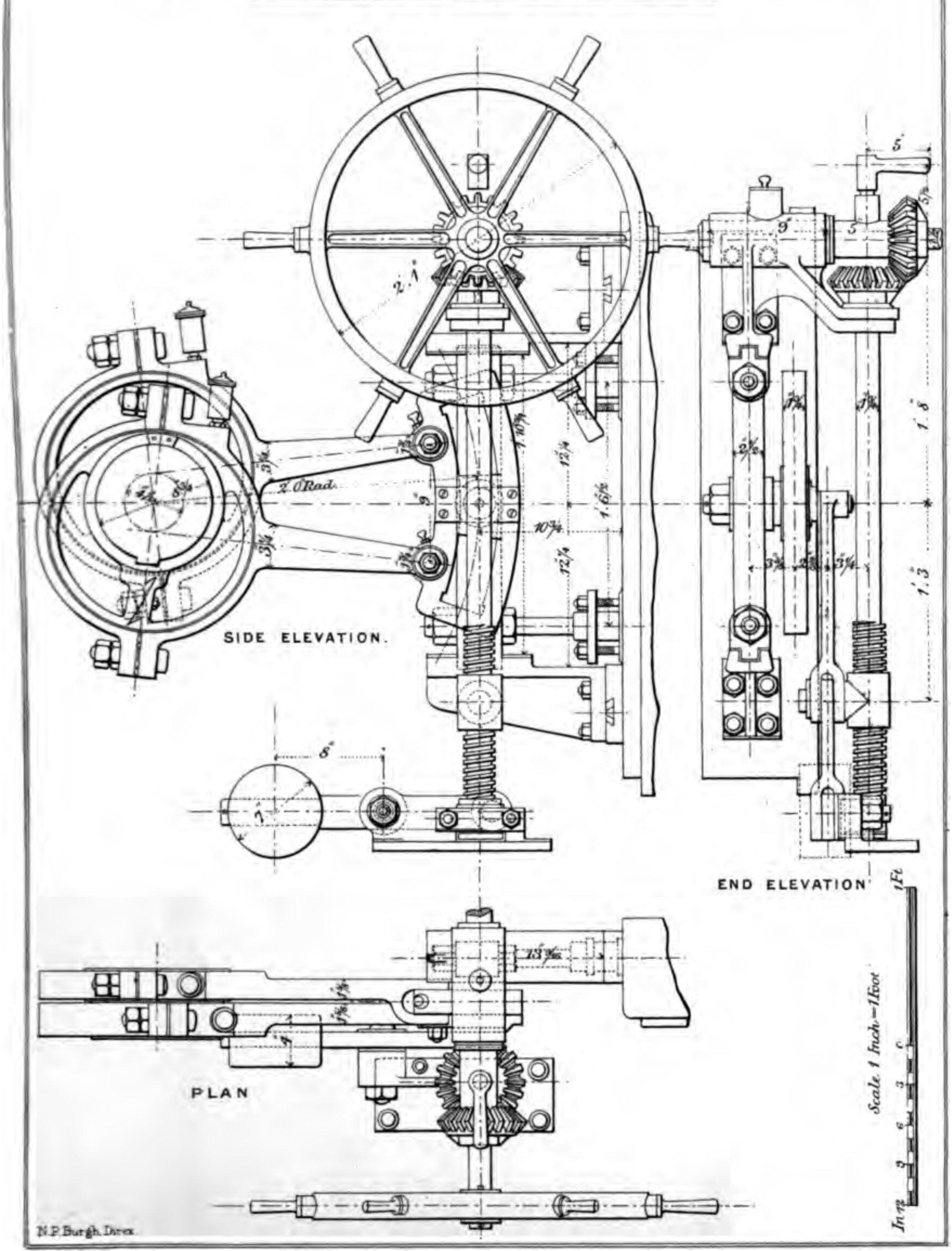
END SECTIONAL ELEVATION.

Main Valve cuts off at ⅝ the Stroke of Piston
Expansion . . . ⅝ to ⅜

P. Burgh, Drex

E & F N Spon 48, Charing Cross, London

LINK MOTION & REVERSING-GEAR OF TWIN-SCREW ENGINES. 200 HP., NOML. COLLY., FITTED IN S.S. "R.N.", BY N.P. BURCH.

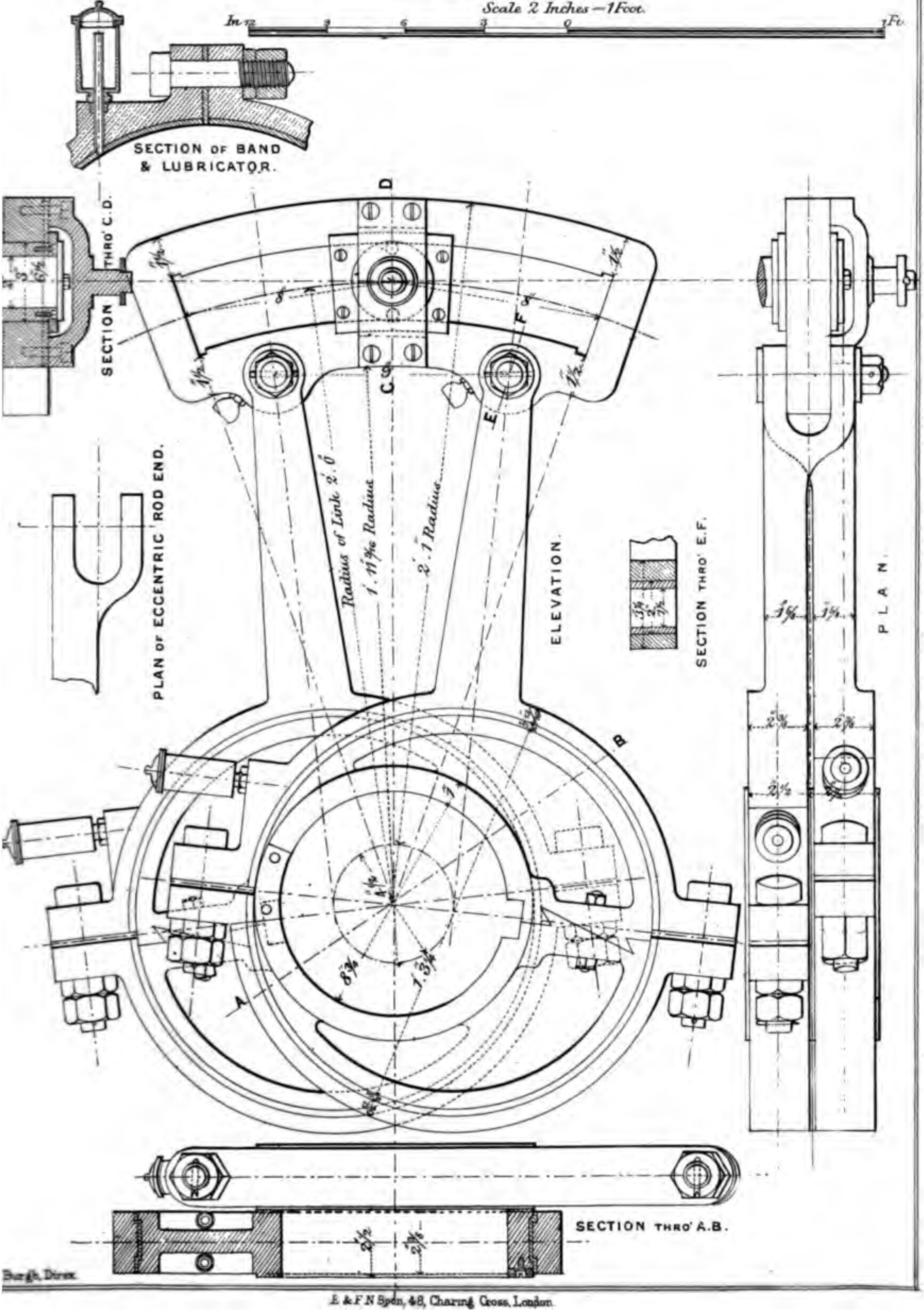


E. & F.N. Spon 48, Charing Cross, London

DETAILS OF LINK MOTION OF TWIN–SCREW ENGINES FITTED IN S.S."R.N." NOML, COLLY,

BY N.P. BURCH.

Scale 2 Inches – 1 Foot.

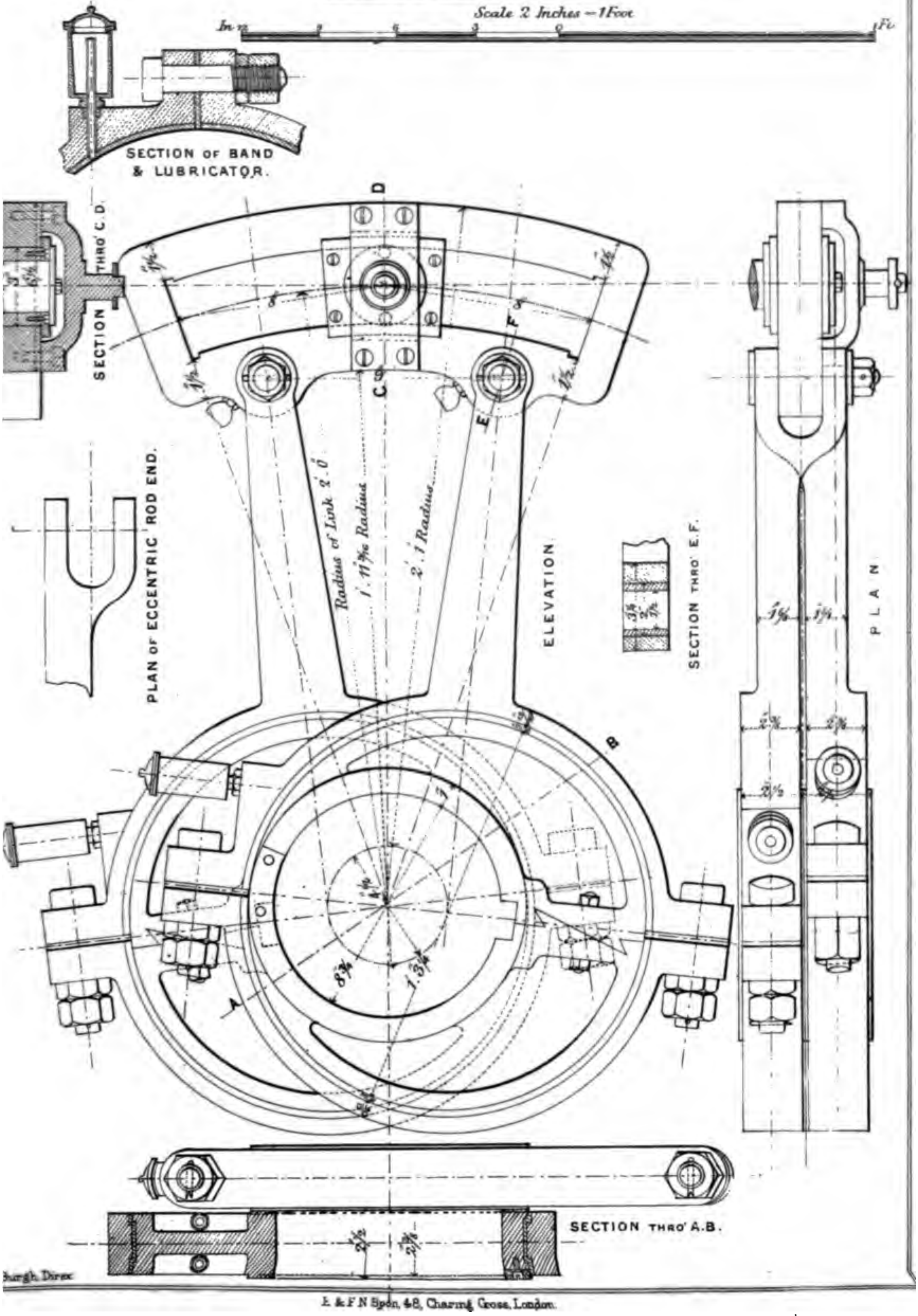


Burgh, Direx.

E & F N Spon, 48, Charing Cross, London.

Plate 31

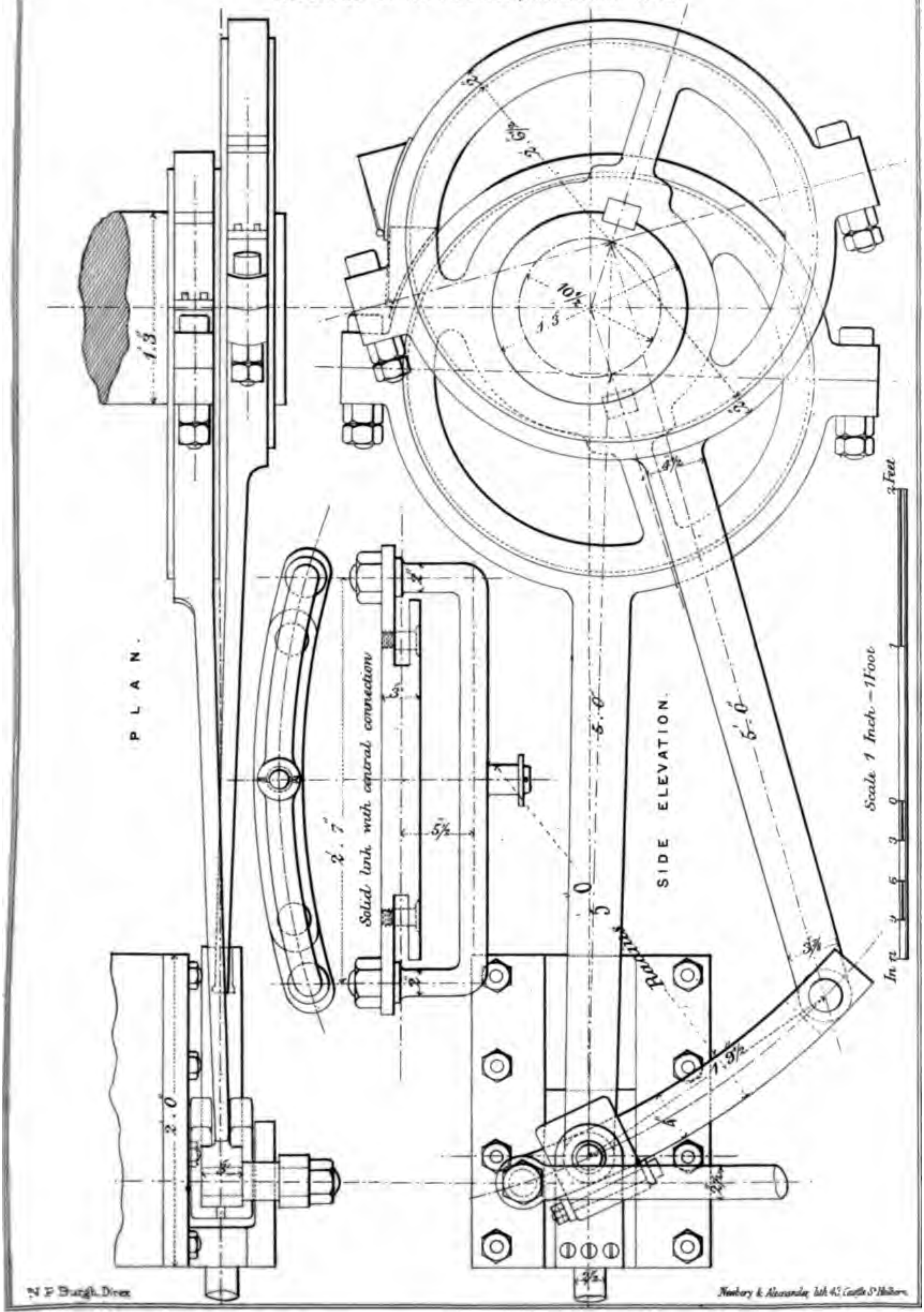
DETAILS OF LINK MOTION OF TWIN-SCREW ENGINES FITTED IN S.S. "R.N." NOML, COLLY,
BY N.P. BURCH.



urgh Direx

E. & F. N. Spon, 48, Charing Cross, London.

LINK MOTION FOR ENGINES 400 HP. NOML, COLLY, HAVING A SOLID LINK & CENTRAL CONNECTION FOR THE ECCENTRIC-RODS. INVENTED BY N. P. BURGH, IN THE YEAR 1862.

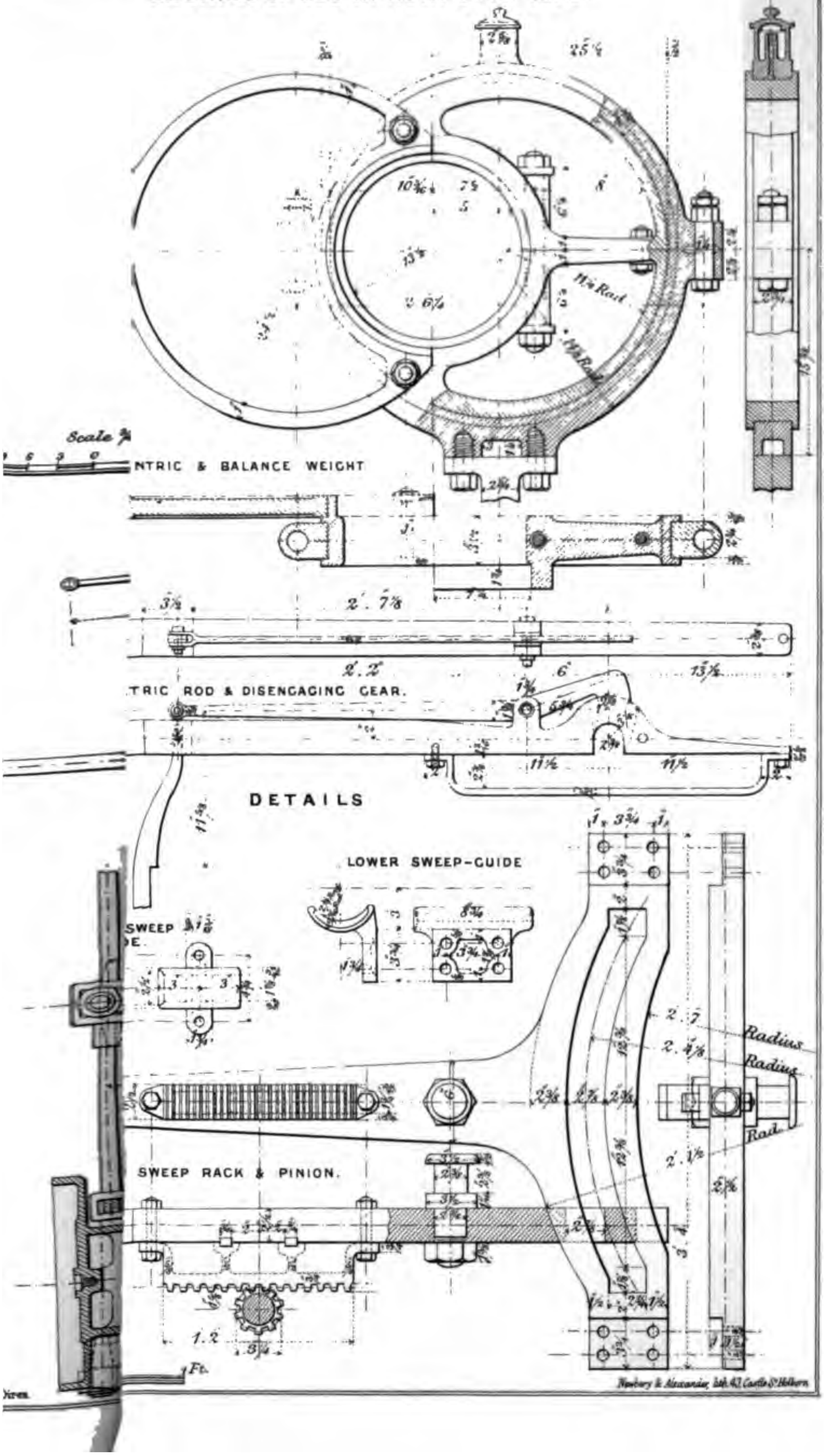


N P Burgh Direx

Newbery & Alexander, lith 43 Castle St Holborn.

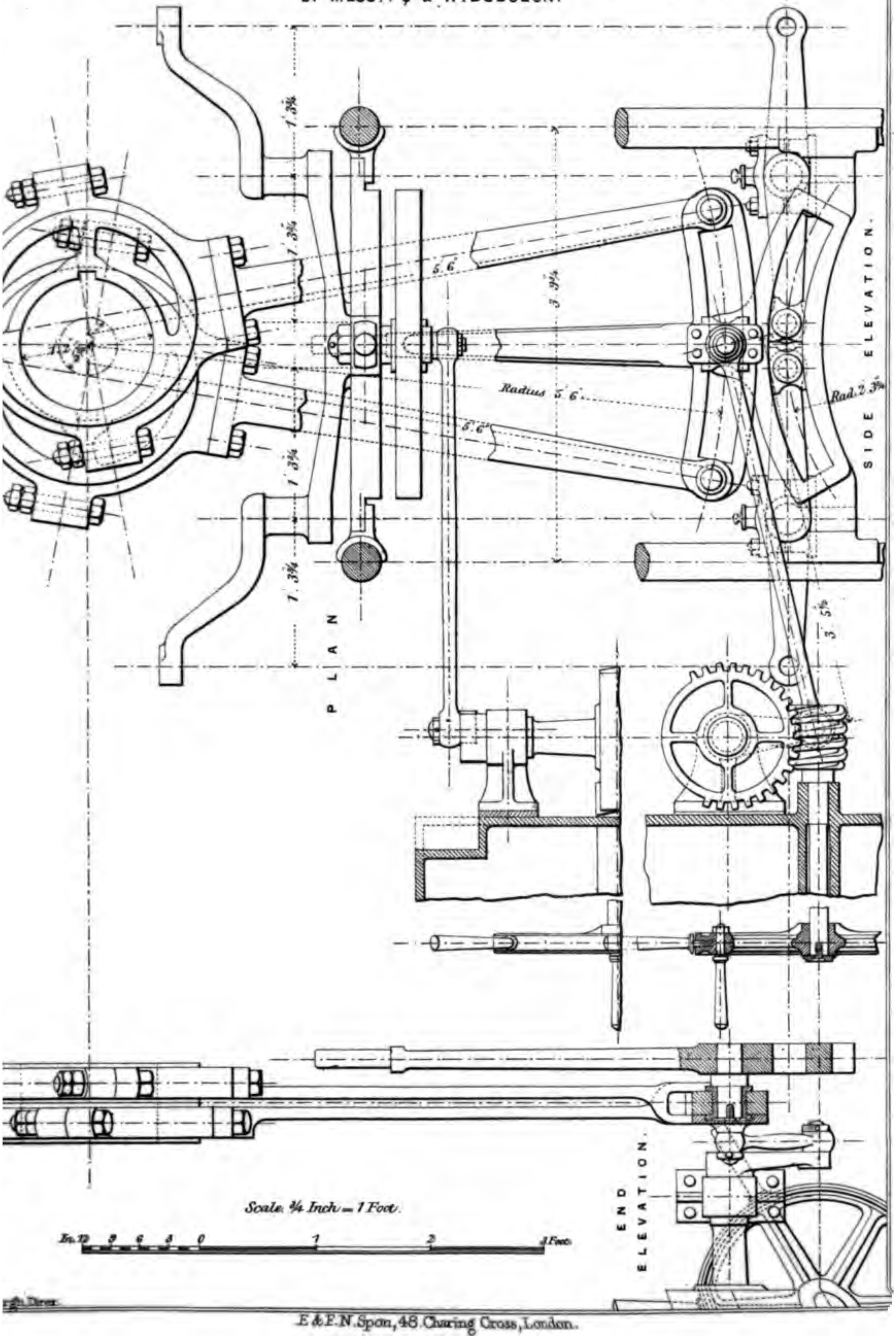
E & F N Spon, 48, Charing Cross, London.

ENGINES OF 250 HP. NOML. COLLY. 1870.



Newbury & Alexander, lith. 42, Castle St Holborn

ARRANGEMENT OF LINK MOTION & REVERSING GEAR OF OSCILLATING ENGINES OF 200 HP. NOML COLLY
BY MESSRS J & W. DUDGEON.



Scale ¾ Inch = 1 Foot.

E & F. N. Spon, 48 Charing Cross, London.

LINK MOTION & REVERSING GEAR FOR OSCILLATING ENGINES.

120. HP. NOML COLLY

BY MESSRS JAMES WATT, & Co

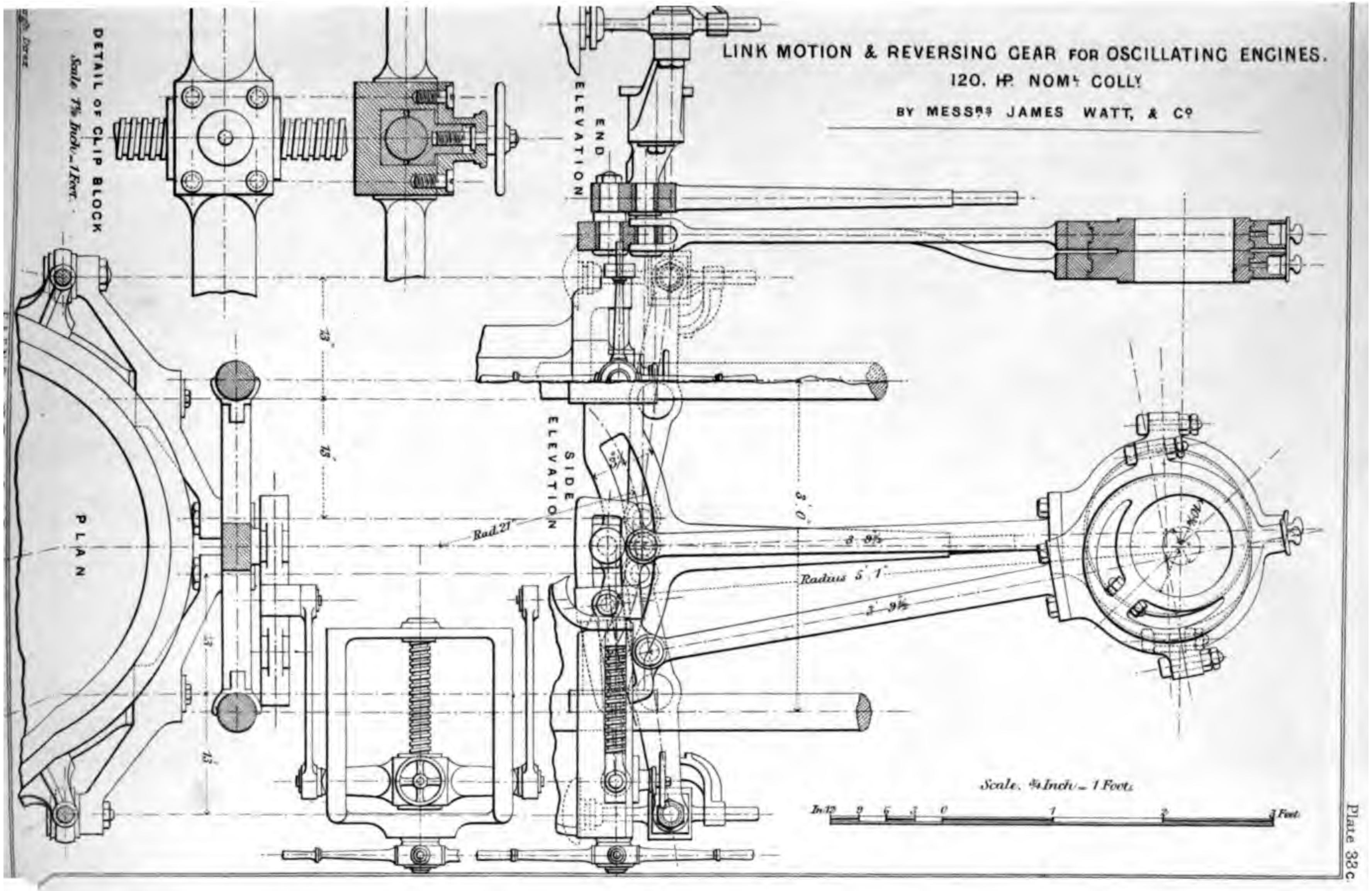
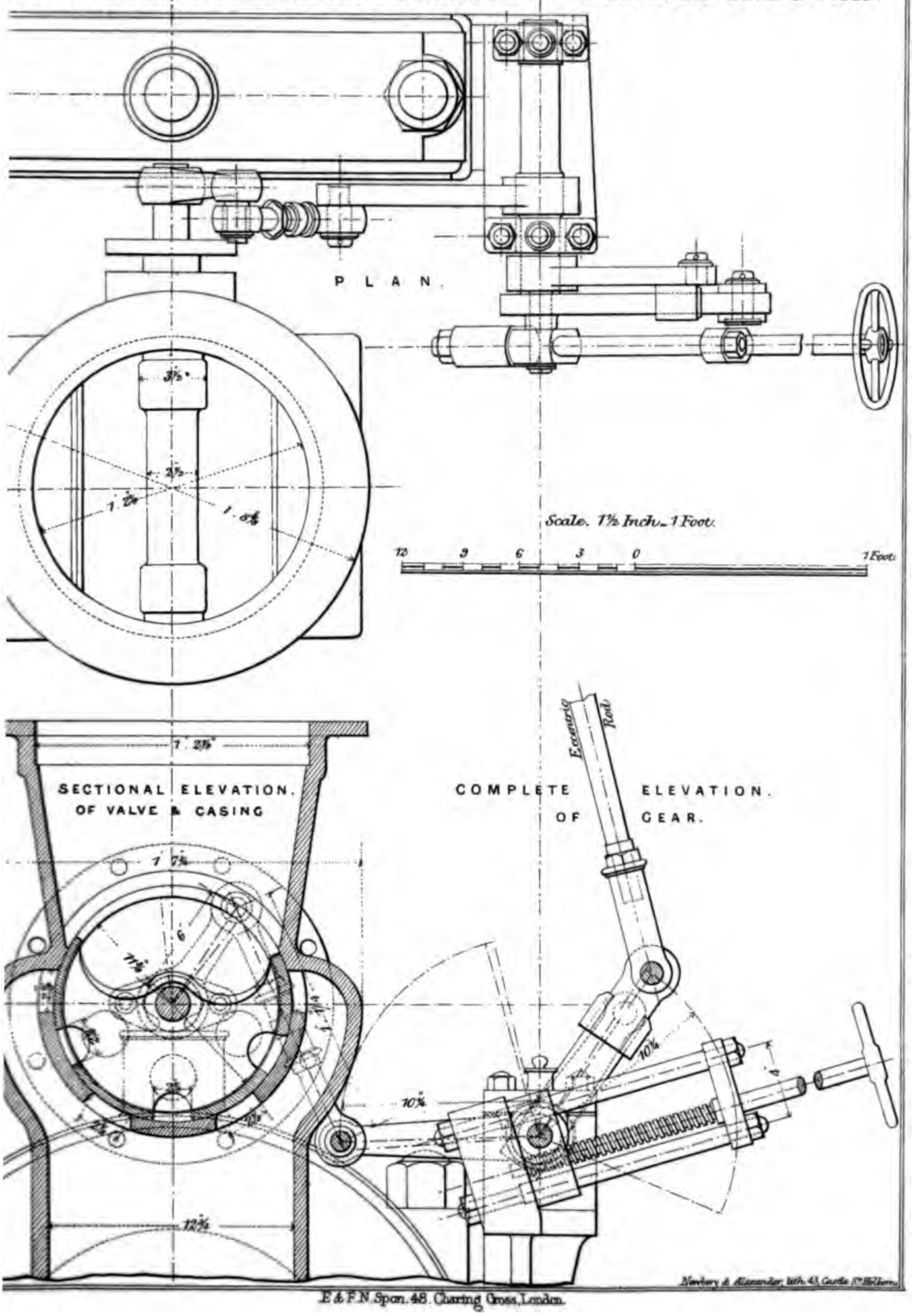


Plate 33 D.

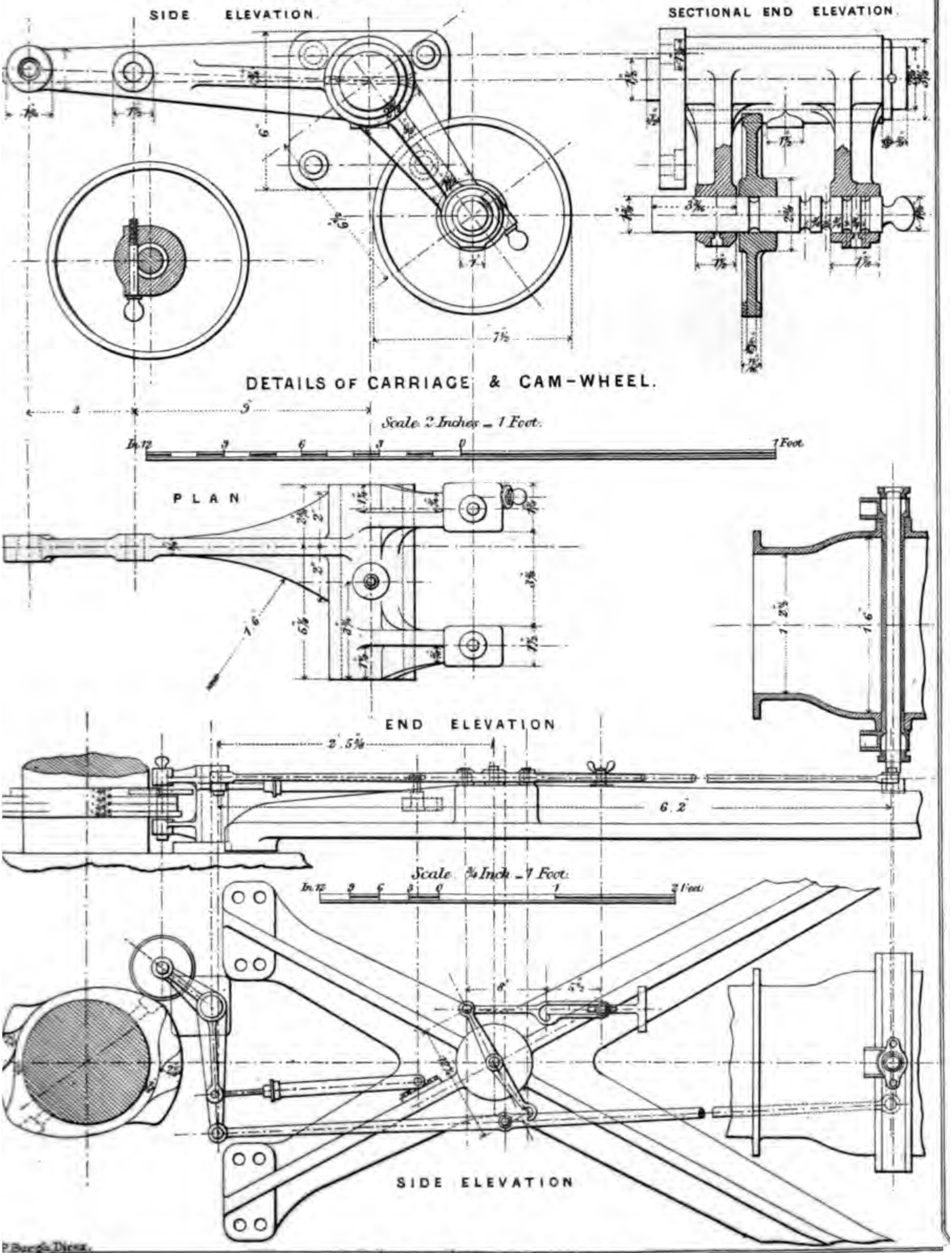
XPANSION GEAR FOR OSCILLATING ENGINES BY MESSRS MAUDSLAY SONS & FIELD.


P L A N.
3½
2½
1. 2½
1. 6¾
Scale. 1½ Inch = 1 Foot.
12
9
6
3
0
1 Foot.
7. 2½
SECTIONAL ELEVATION. OF VALVE & CASING
COMPLETE ELEVATION. OF GEAR.
Eccentric Rod
1. 7¾
6
11½
10¾
10¾
4
12½
Newbery & Alexander, lith. 43, Castle St. Holborn.

E. & F. N. Spon. 48. Charing Cross, London.

GENERAL CAM-EXPANSION GEAR FOR OSCILLATING PADDLE-WHEEL ENGINES.

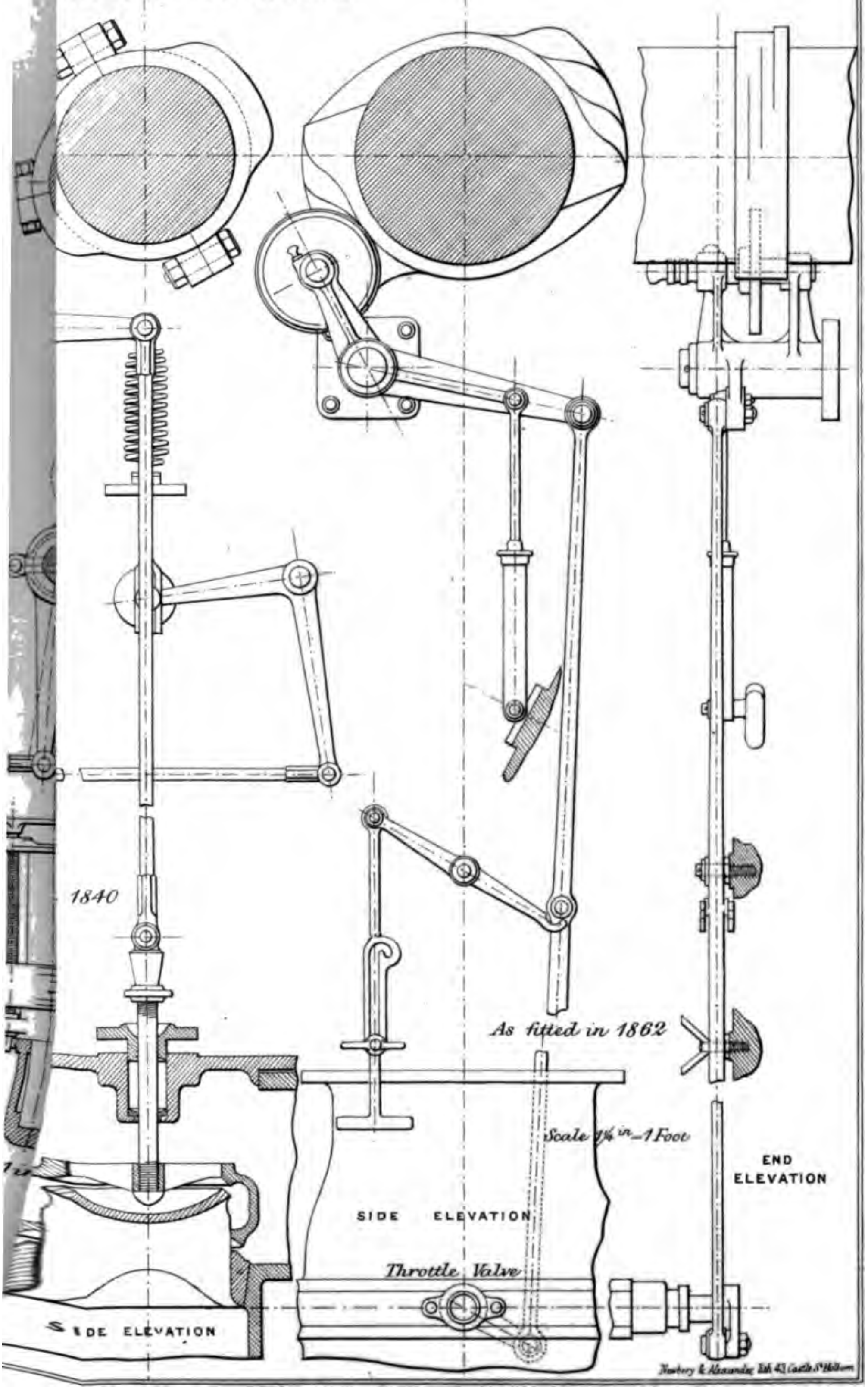
250 HP. NOML. COLLY 1870.



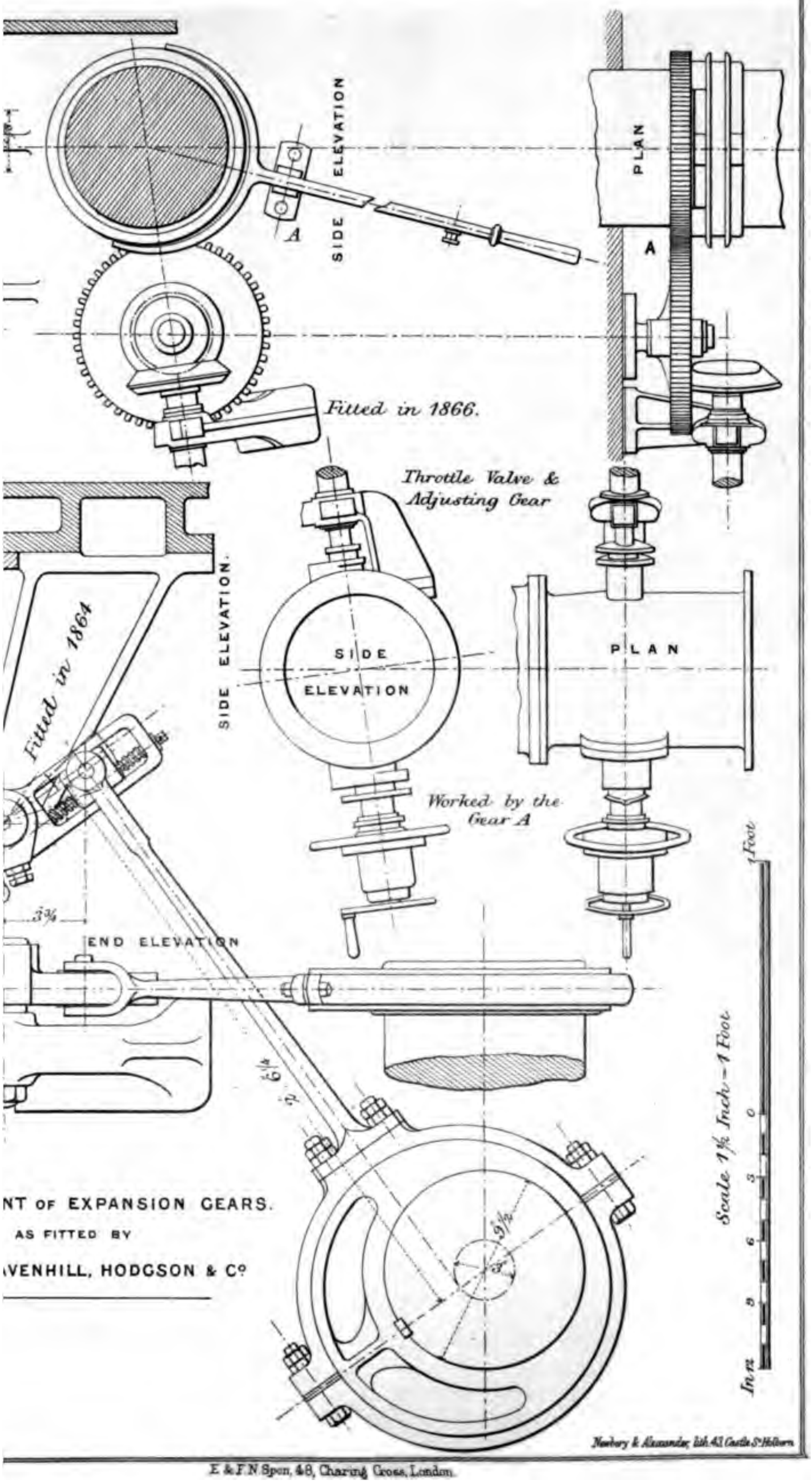
P. Burgh Direx.

E & F.N. Spon, 48, Charing Cross. London.

HILL, HODGSON & Co.



Newbery & Alexander Lith. 43 Castle S^t Holborn



NT OF EXPANSION GEARS.

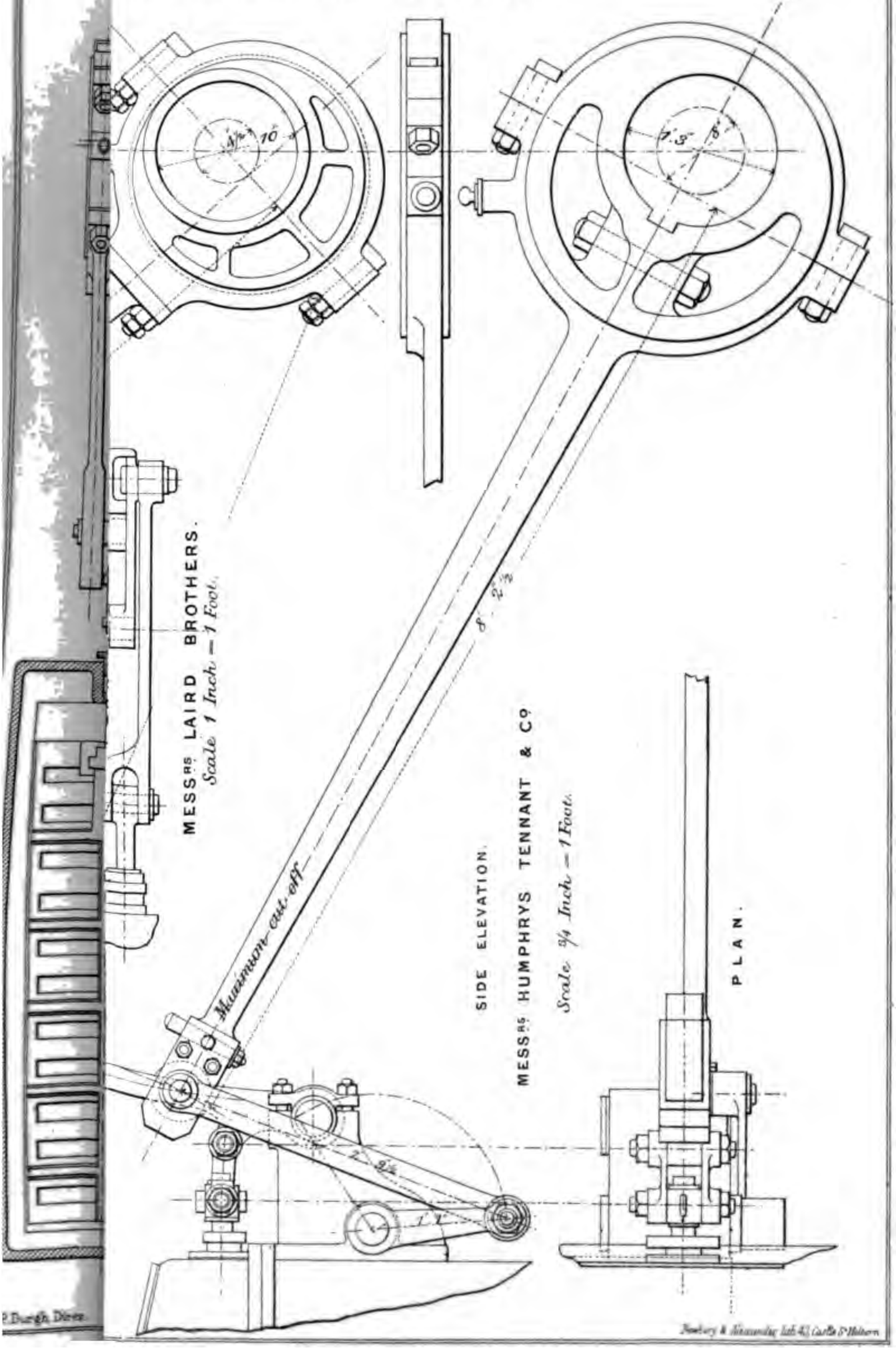
AS FITTED BY

VENHILL, HODGSON & Co

Newbury & Alexander, lith 43 Castle St Holborn

E. & F.N Spon, 48, Charing Cross, London.

ES AS USED IN THE YEAR 1870.

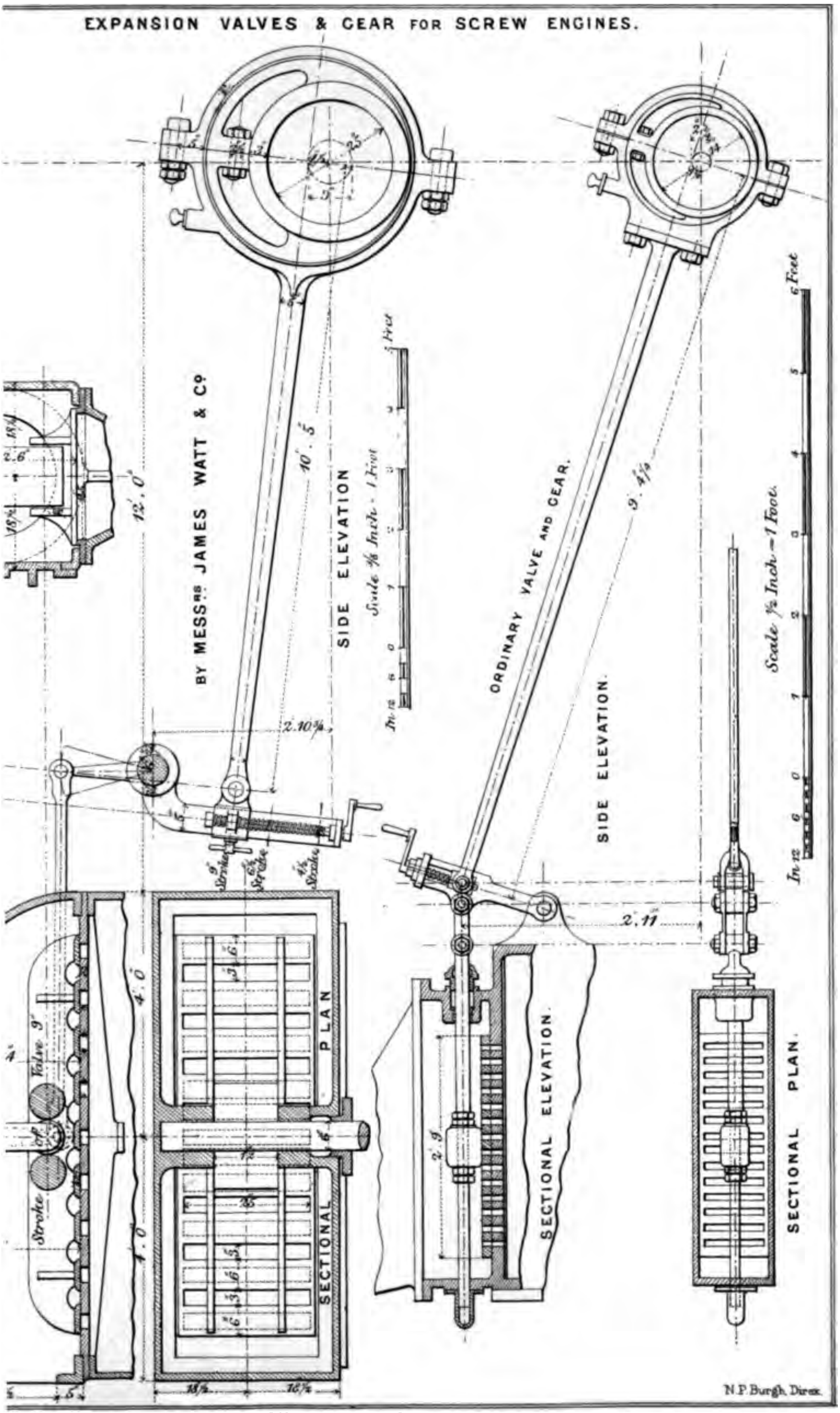


P. Burgh Direx.

Newbury & Alexander Lith 43 Castle St Holborn

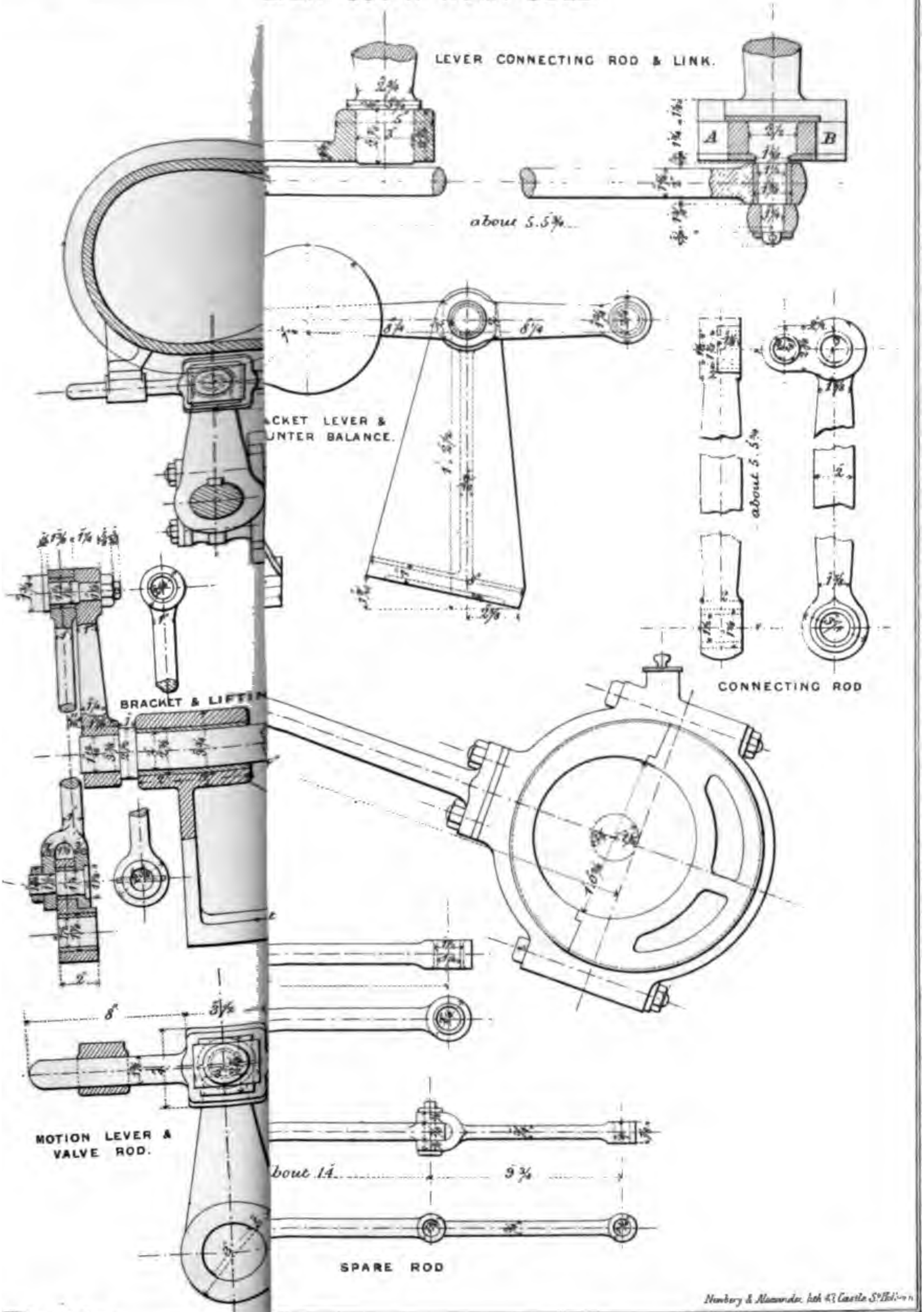
Plate 37.

EXPANSION VALVES & GEAR FOR SCREW ENGINES.



E & F N Spon, 48, Charing Cross, London

LIEH" 350 HP NOML COLLY

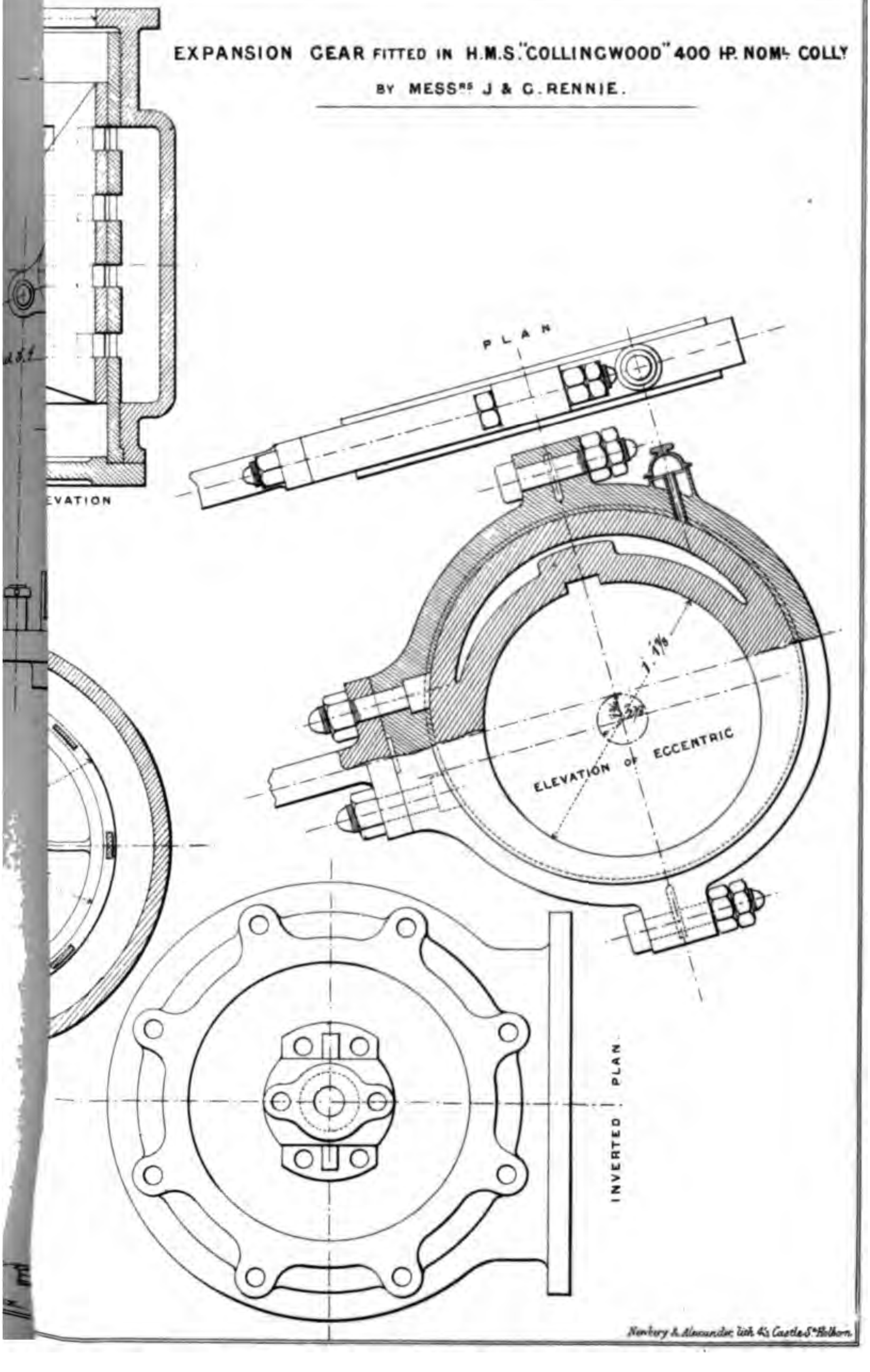


N.P. Burgh Drew.

Newbery & Alexander, lith 43 Castle St Holborn

EXPANSION GEAR FITTED IN H.M.S. "COLLINGWOOD" 400 HP. NOML. COLLY

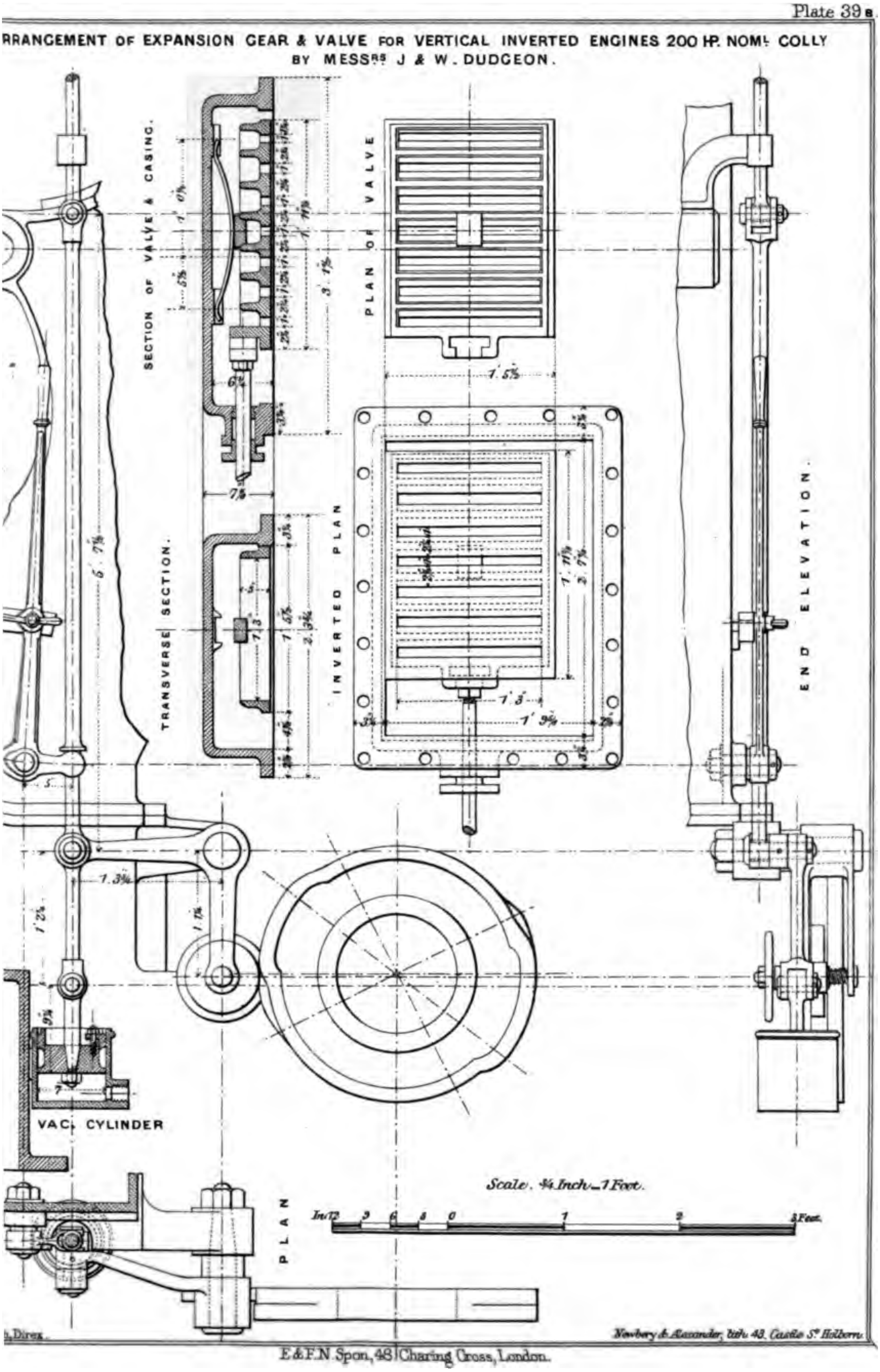
BY MESSRS J & G. RENNIE.



Newbury & Alexander, lith. 4½ Castle St. Holborn.

RRANGEMENT OF EXPANSION GEAR & VALVE FOR VERTICAL INVERTED ENGINES 200 HP. NOML COLLY

BY MESSRS J & W. DUDGEON.

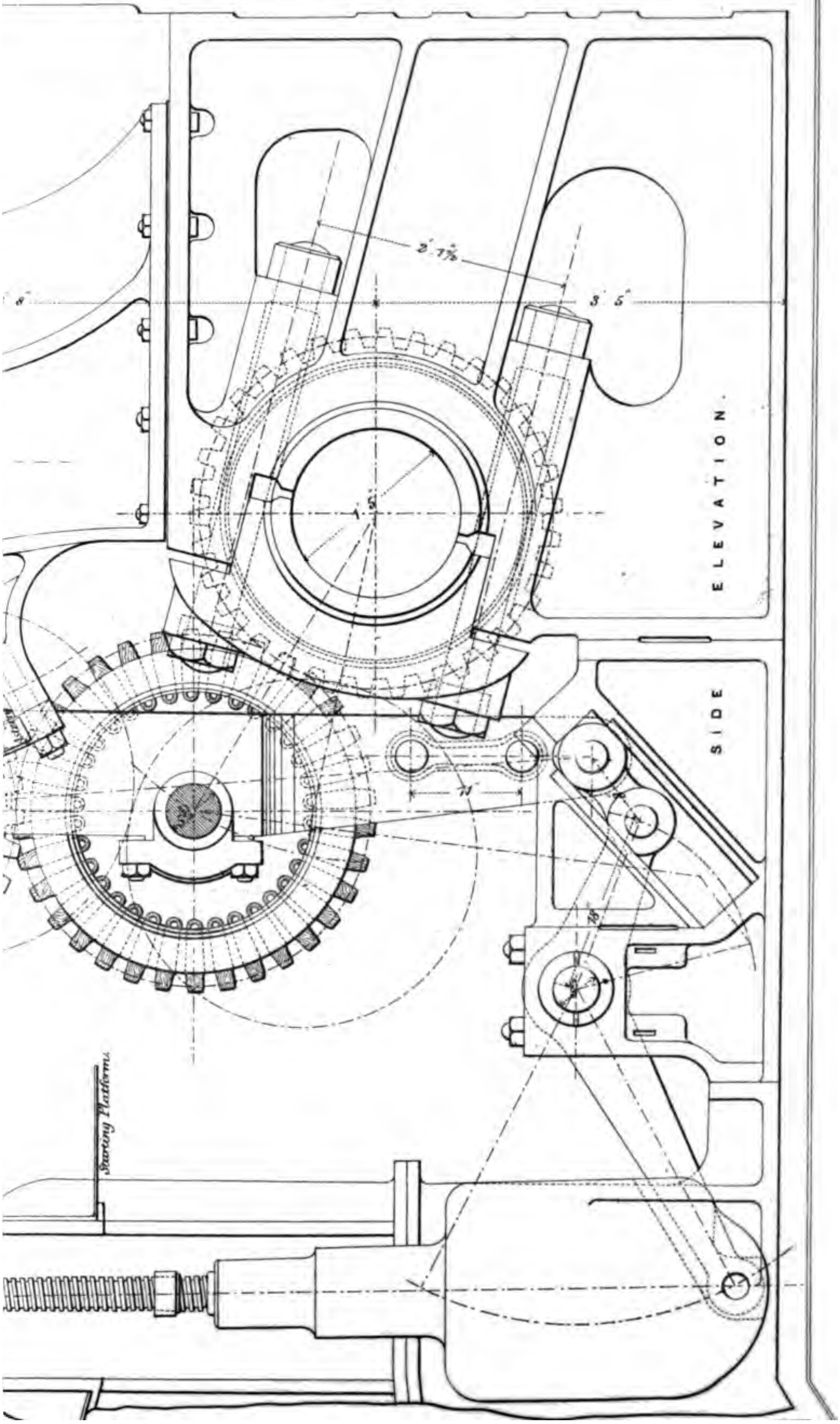


…h, Direx.

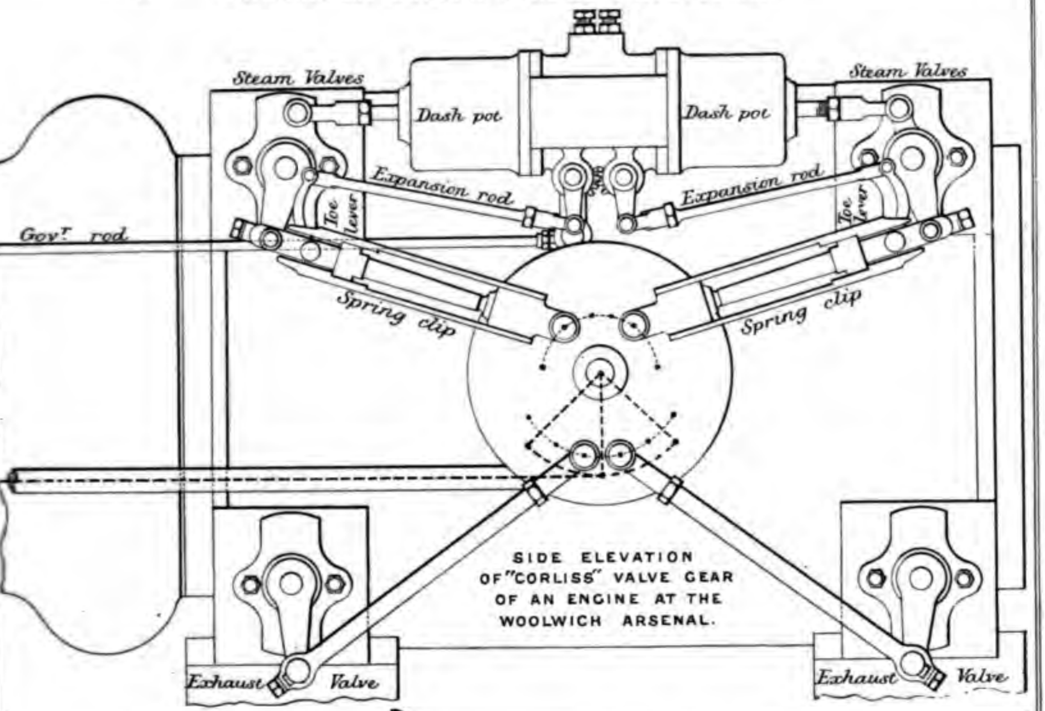
Newbery & Alexander, lith. 43, Castle St Holborn.

E & F.N. Spon, 48 Charing Cross, London.

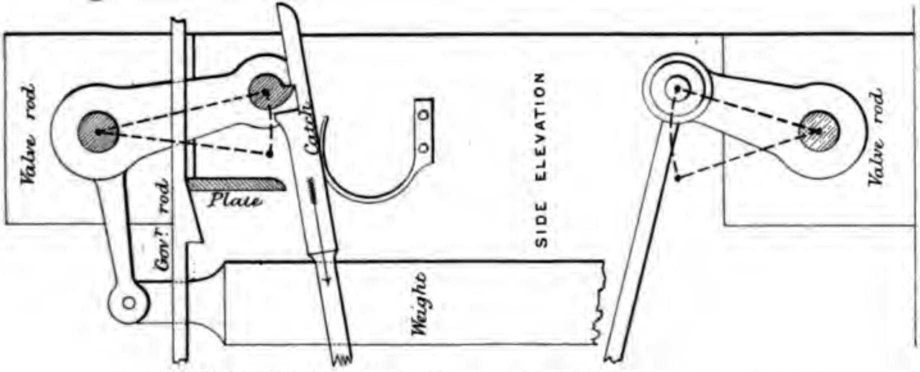
IL COLLY BY MESSRS MAUDSLAY SONS & FIELD.



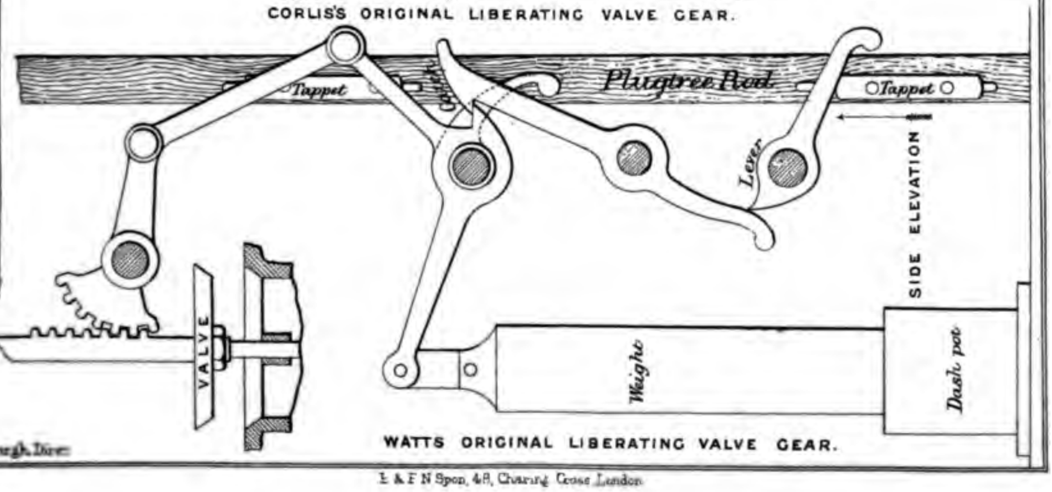
ORIGINAL AND MODERN "CORLISS" VALVE GEARS.



SIDE ELEVATION OF "CORLISS" VALVE GEAR OF AN ENGINE AT THE WOOLWICH ARSENAL.



CORLIS'S ORIGINAL LIBERATING VALVE GEAR.

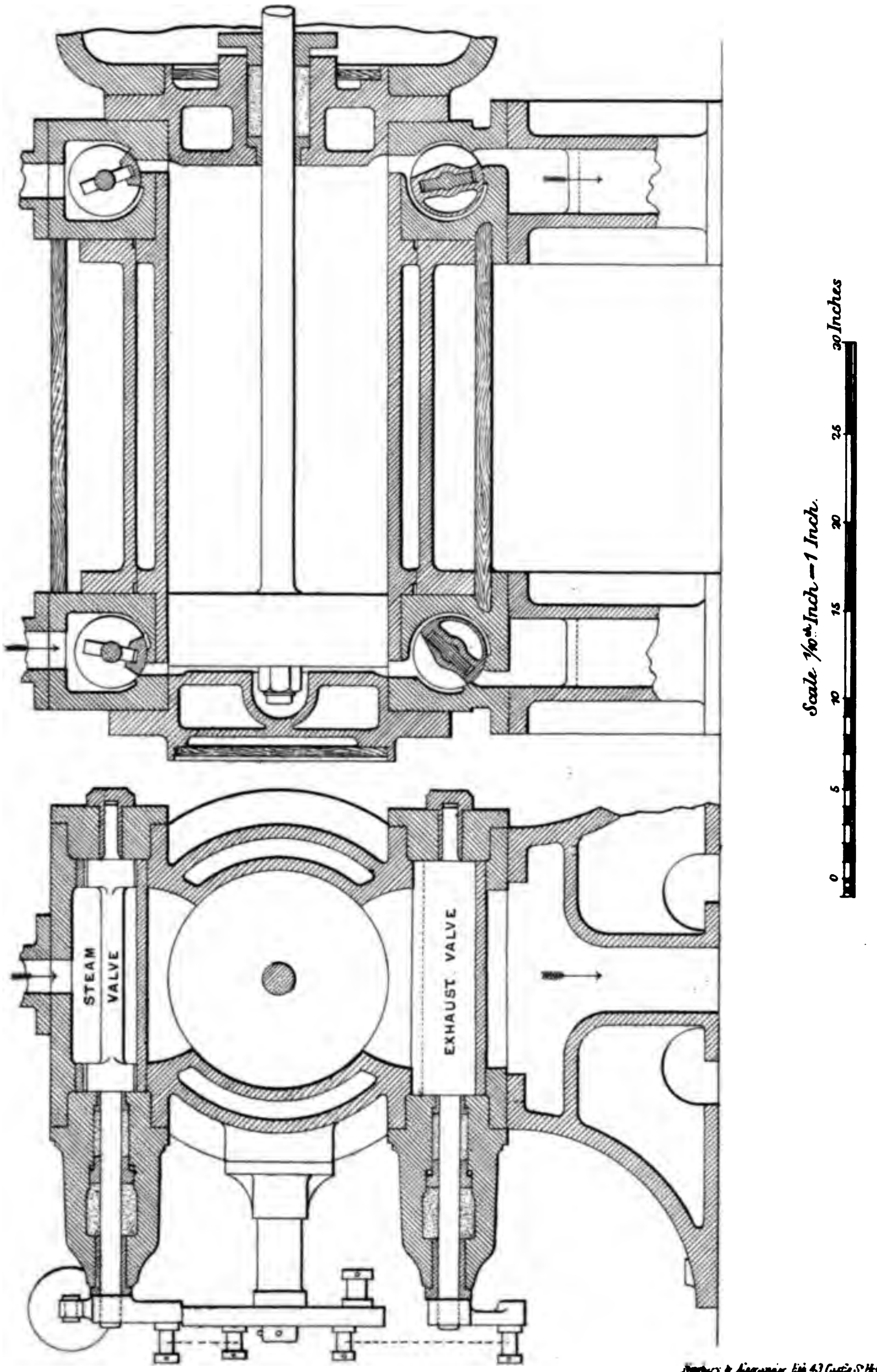


WATTS ORIGINAL LIBERATING VALVE GEAR.

S.P.Burgh, Direx

E & F N Spon, 48, Charing Cross London

SECTIONAL ELEVATION OF THE CORLISS-VALVES, GEAR, AND CYLINDER OF THE HORIZONTAL ENGINE AT THE WOOLWICH ARSENAL.



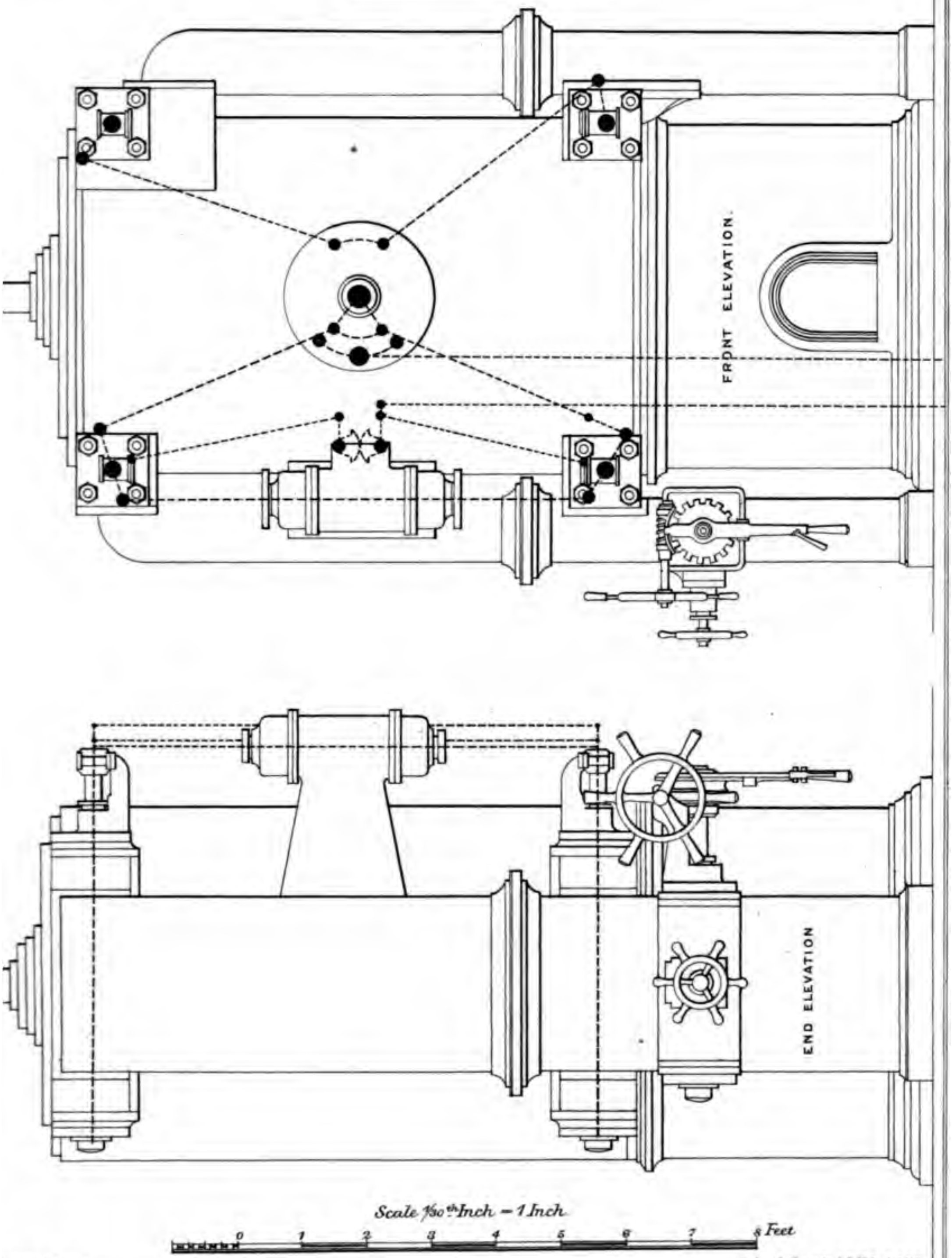
N. P. Burgh. Direx.

Newbury & Alexander, Lith 43 Castle S^t Holborn

E & F. N. Spon 48, Charing Cross, London.

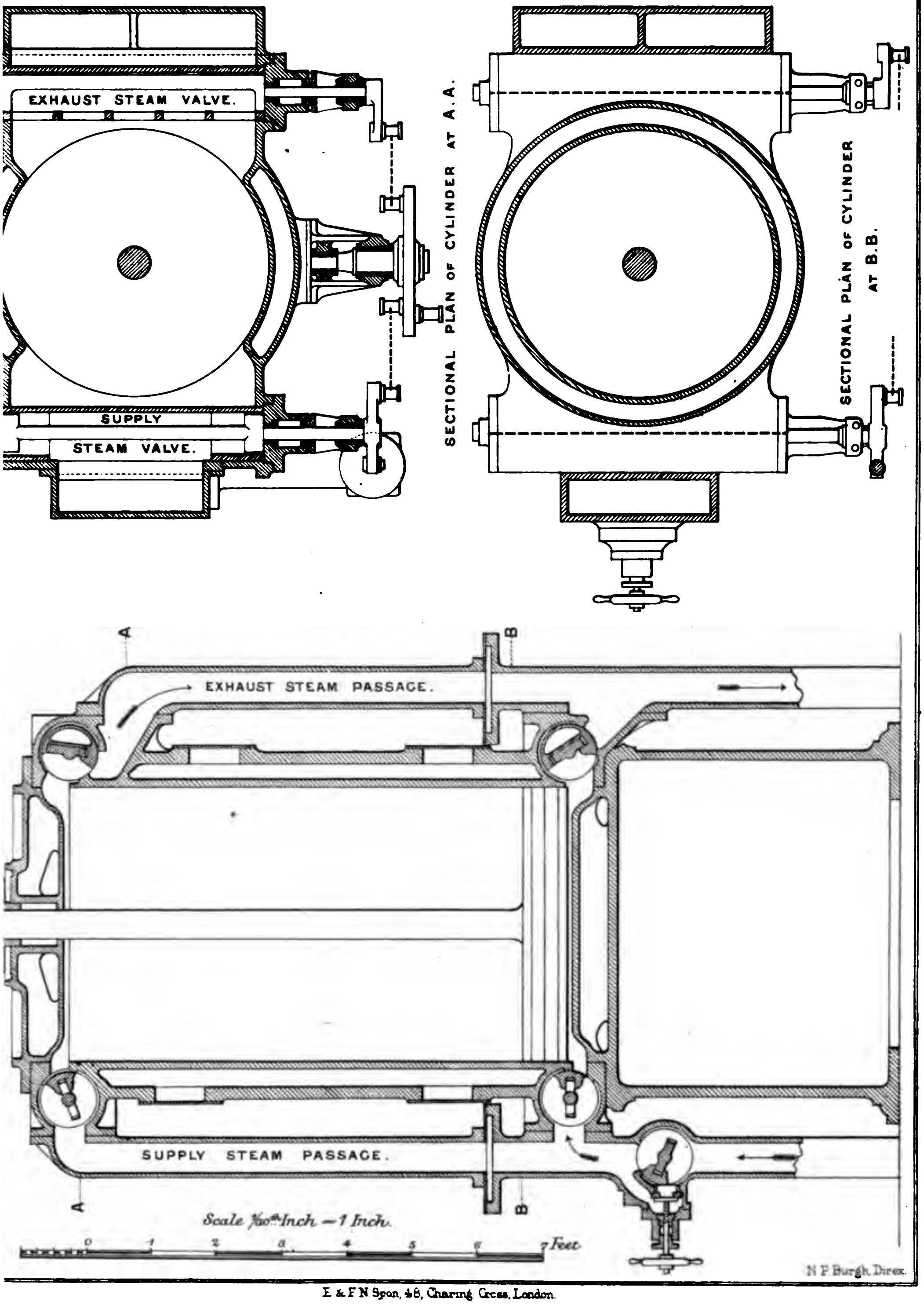
ELEVATION OF "CORLISS" VALVE GEAR, AND CYLINDER OF THE BEAM ENGINE ERECTED AT SALTAIRE.

BY MESSRS HICK, HARGREAVES & Co



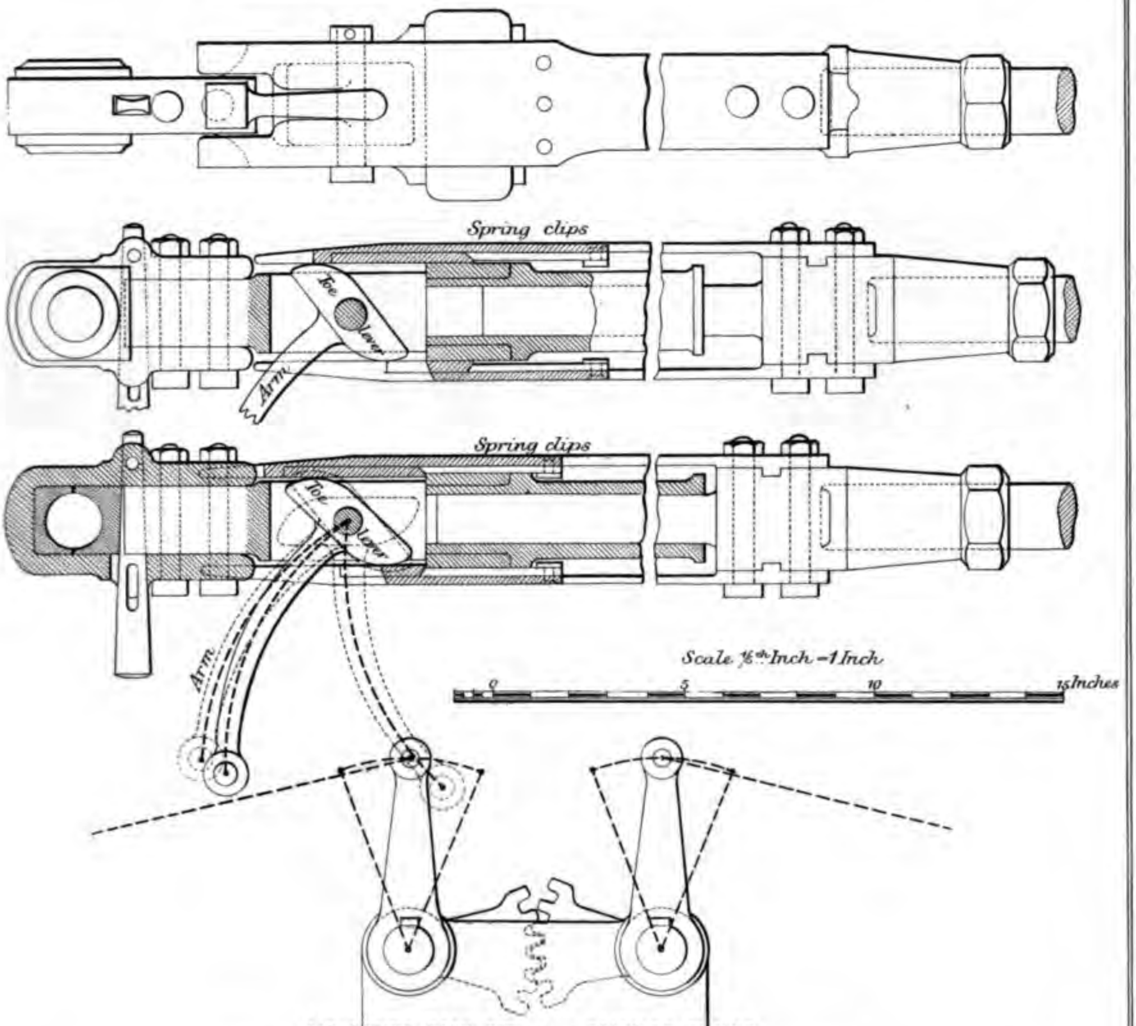
Burgh, Direx.
Newbury & Alexander lith. 43 Castle St Holbo
E. & F. N. Spon, 48, Charing Cross, London.

SECTIONS OF THE CYLINDER & VALVES ERECTED AT SALTAIRE.

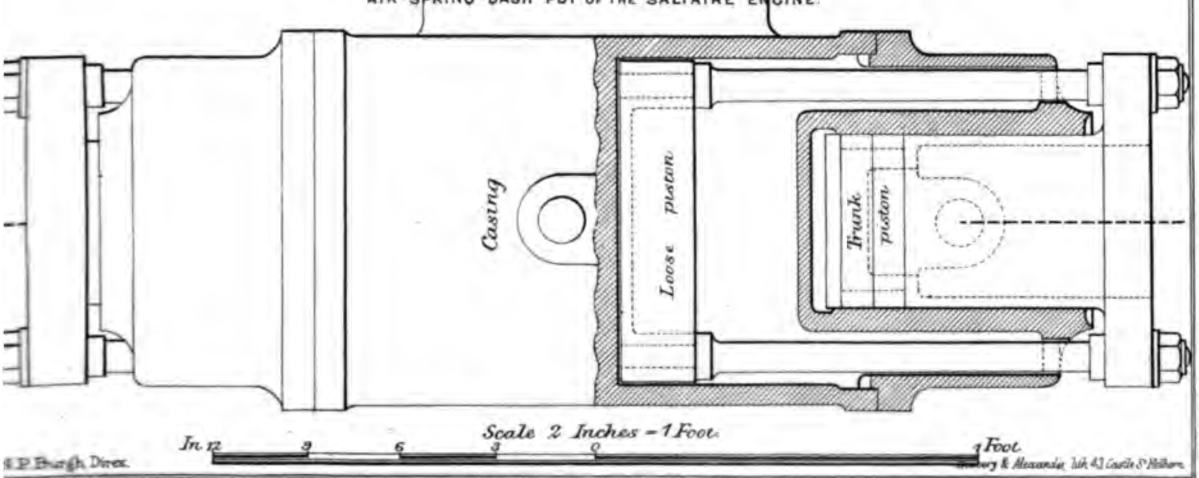


E. & F. N. Spon, 46, Charing Cross, London.

LIBERATING GEAR FOR "CORLISS" VALVES. BY MESSRS SPENCER & INGLIS.



AIR-SPRING-DASH POT OF THE SALTAIRE ENGINE.



P. Burgh Direx.

ry & Alexander, lith. 43 Castle St Holborn

E. & F. N. Spon, 48, Charing Cross, London.

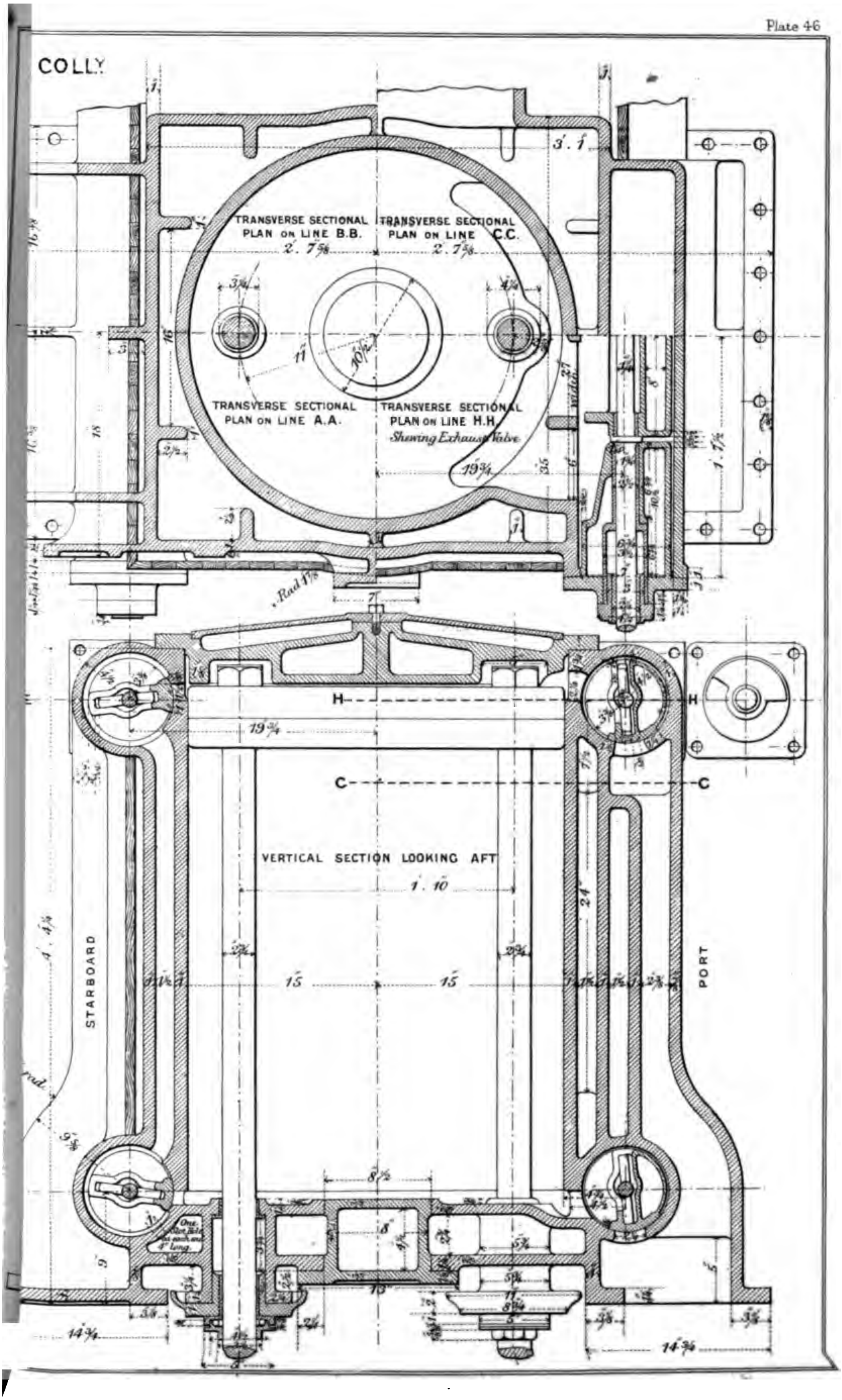
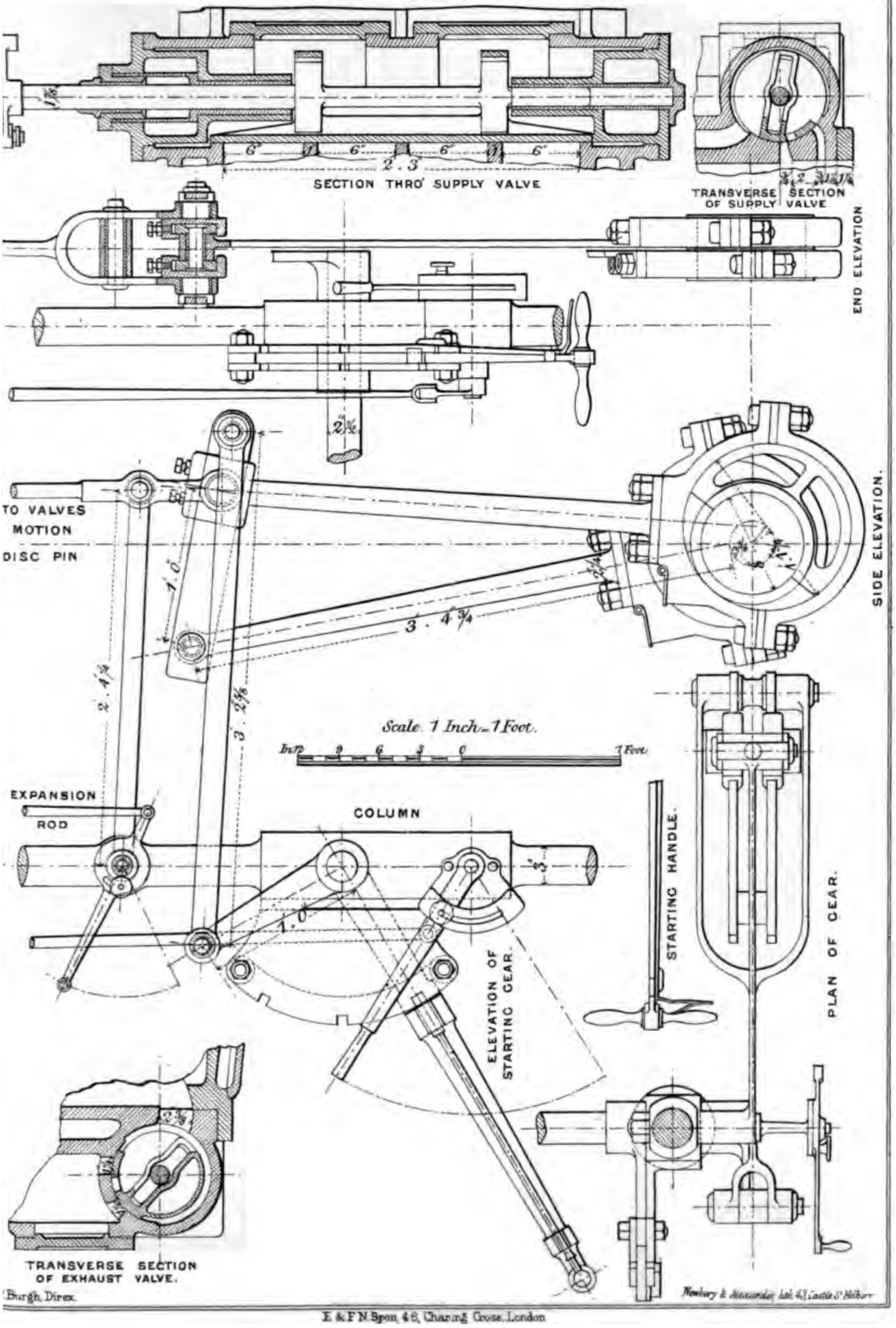

COLLY
TRANSVERSE SECTIONAL PLAN ON LINE B.B.
2'. 7⅝
TRANSVERSE SECTIONAL PLAN ON LINE C.C.
2'. 7⅝
TRANSVERSE SECTIONAL PLAN ON LINE A.A.
TRANSVERSE SECTIONAL PLAN ON LINE H.H.
Shewing Exhaust Valve
19¾
3'. 1
1'. 1½
Rad 1⅞
H
H
19¾
C
C
VERTICAL SECTION LOOKING AFT
1'. 10
15
15
24
STARBOARD
PORT
4'. 4¾
8½
14¾
14¾

Plate 47.

…NK-MOTION, STARTING-GEAR & DOUBLE PORTED "CORLISS" VALVES. FOR THE MARINE ENGINES 100.HP. NOML. COLLY

BY J. F. SPENCER, ENGINEER.

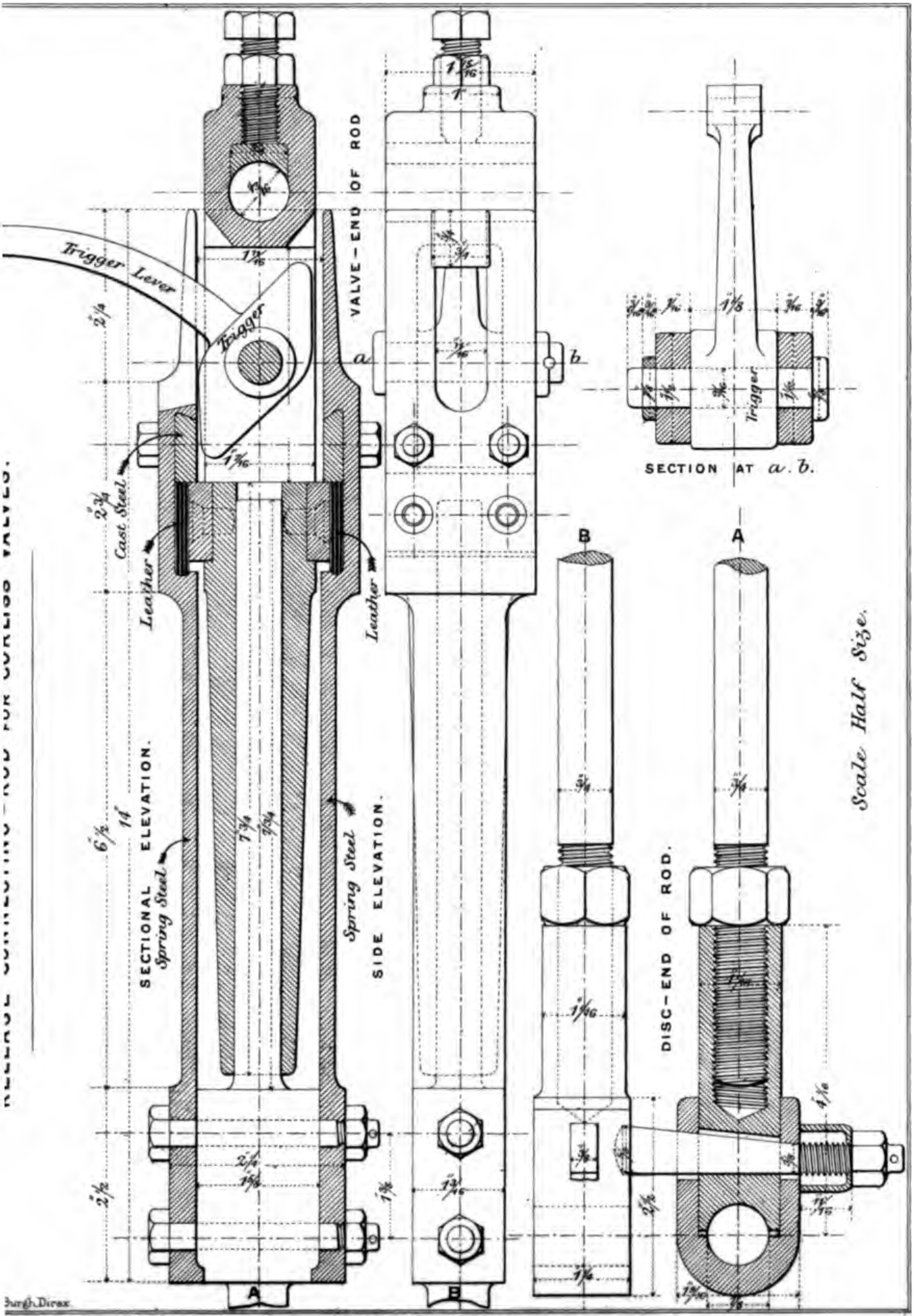


…Burgh, Direx.

Newbury & Alexander, Lith. 43, Castle St. Holborn

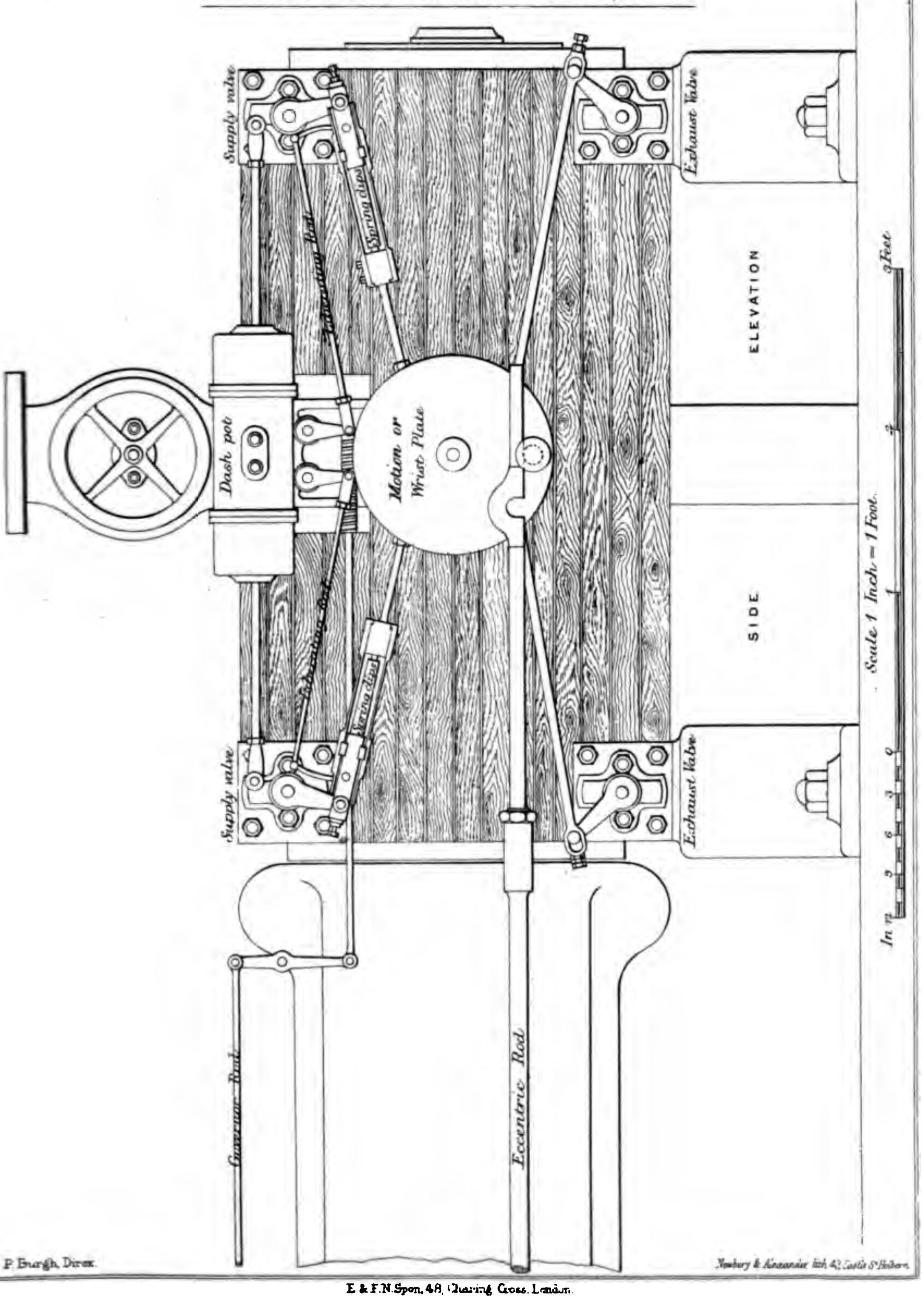
E. & F. N. Spon, 48, Charing Cross, London.

RELEASE CONNECTING-ROD FOR CORLISS VALVES.



E.&F.N. Spon, 48, Charing Cross, London.

ARRANGEMENT OF "CORLISS" VALVE GEAR FOR A HORIZONTAL ENGINE.
CYLINDER 18 INS. DIAMETER, STROKE OF PISTON 4 FEET.
BY MR R. DOUGLAS, ENGINEER, KIRKCALDY.

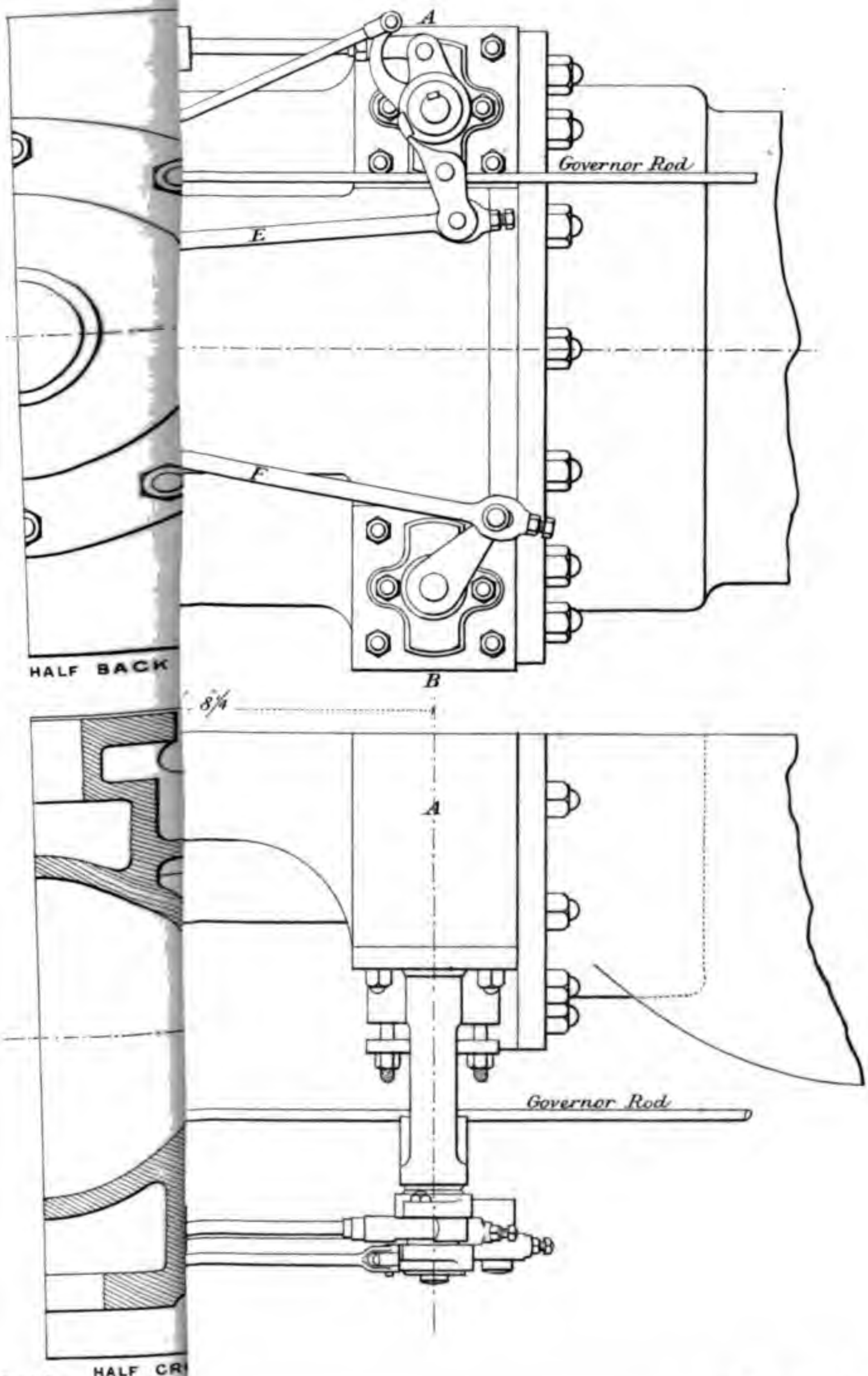


N.P. Burgh, Direx.

Newbury & Alexander lith 42 Castle St Holborn.

E & F.N. Spon, 48, Charing Cross, London.

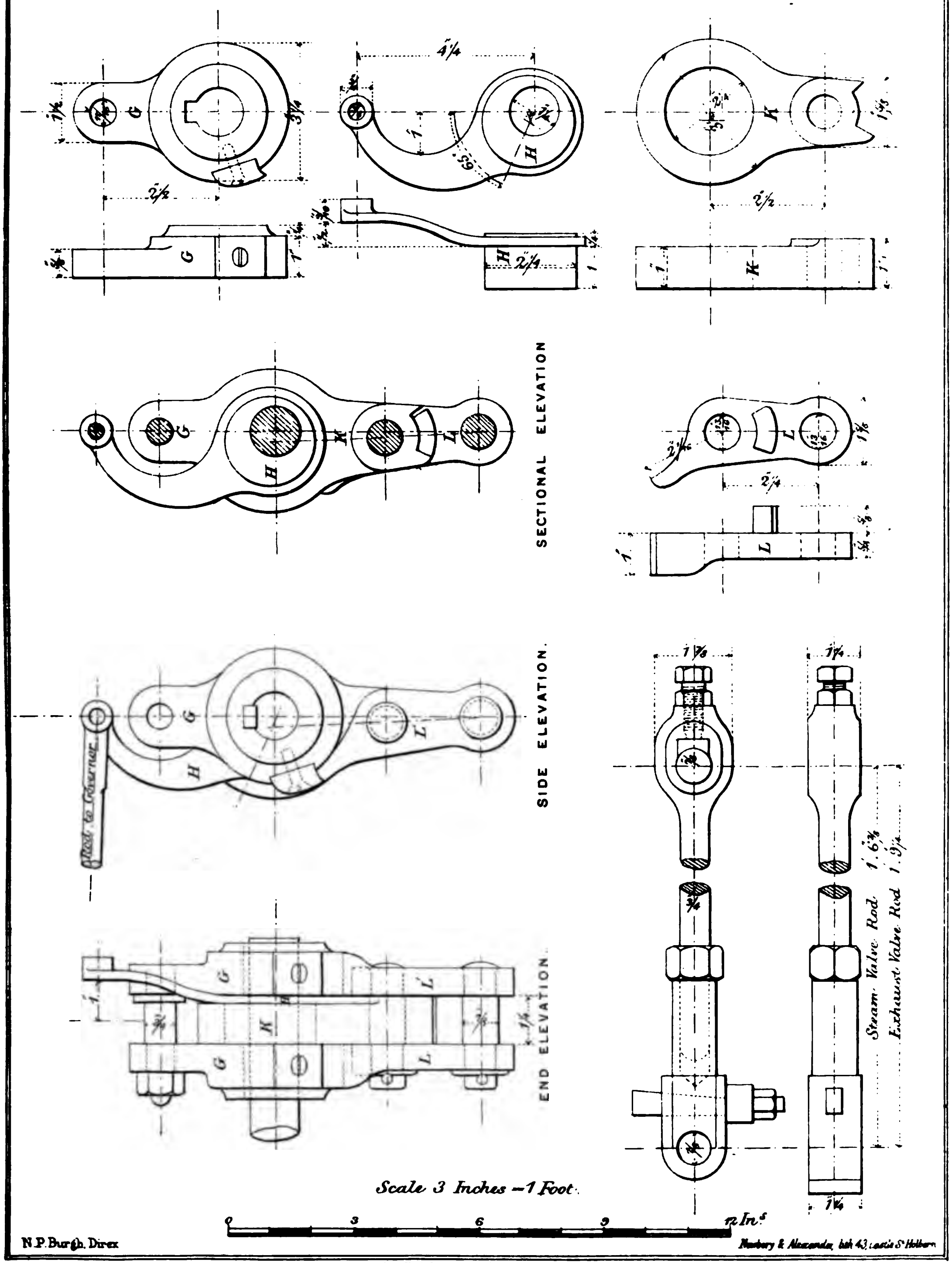
S, DUNNIKIER FOUNDRY, KIRKCALDY, N.B.



Burgh Direx

Newbery & Alexander Lith. 43 Castle St Holborn

DETAILS OF DOUGLAS AND GRANT'S PATENT CUT-OFF GEAR FOR CORLISS ENGINES.



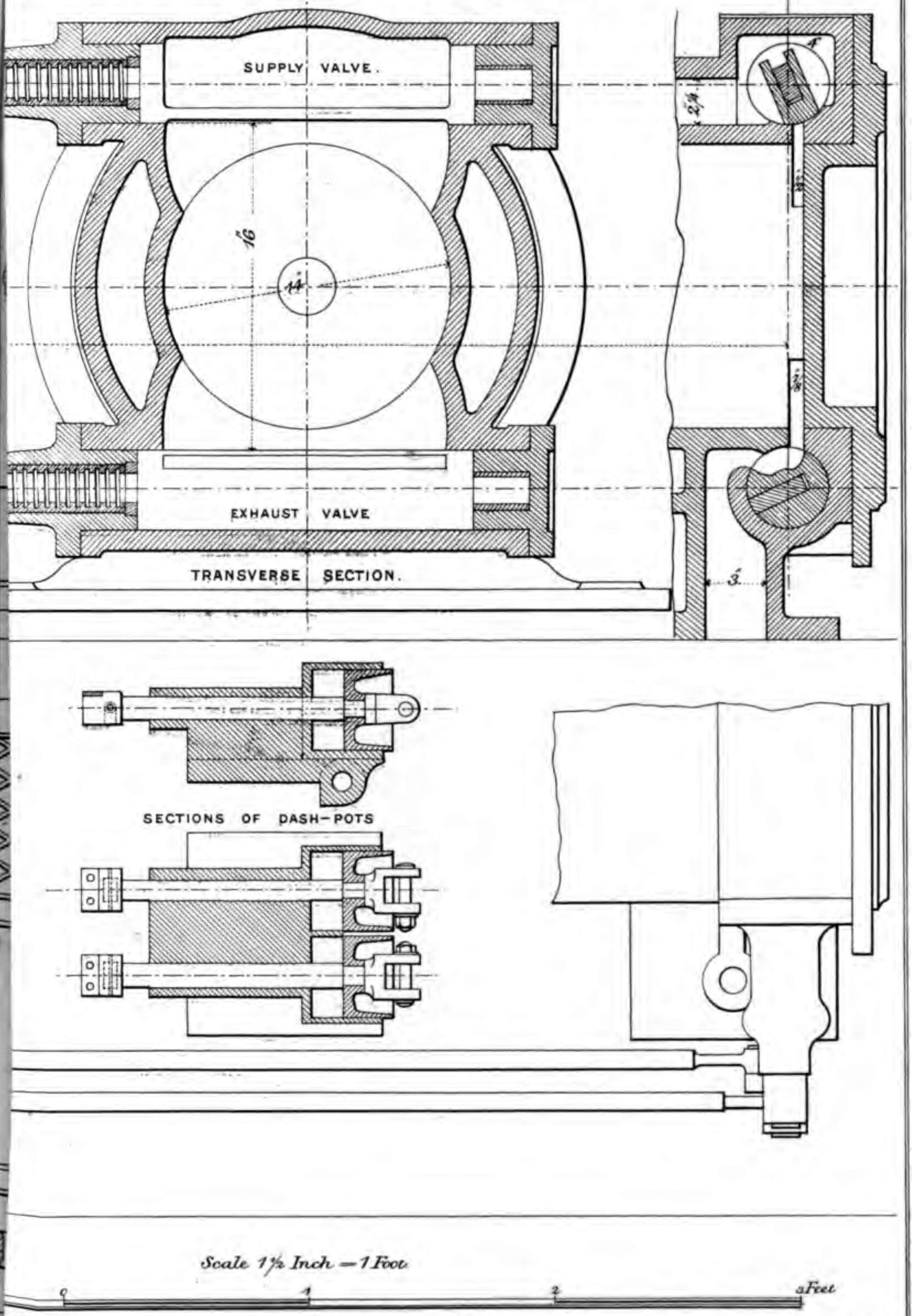
Scale 3 Inches = 1 Foot.

N.P. Burgh. Direx

Newbury & Alexander, lith 43, Castle St Holborn

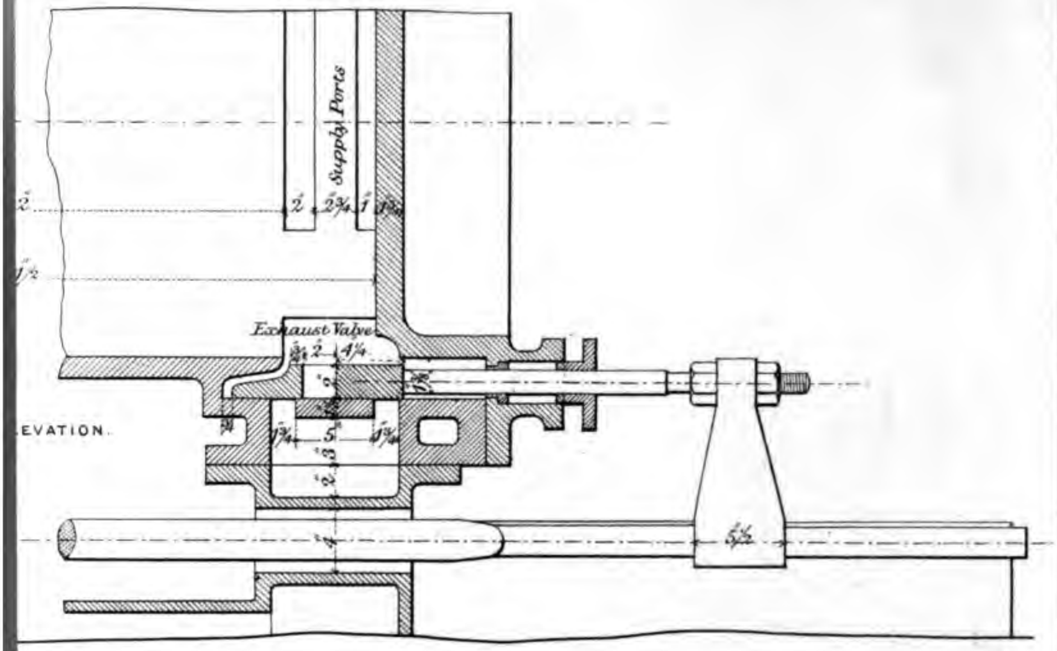
E & F N Spon 48, Charing Cross, London

CT ACTING ENGINE. BY MESSRS J & E. WOOD.



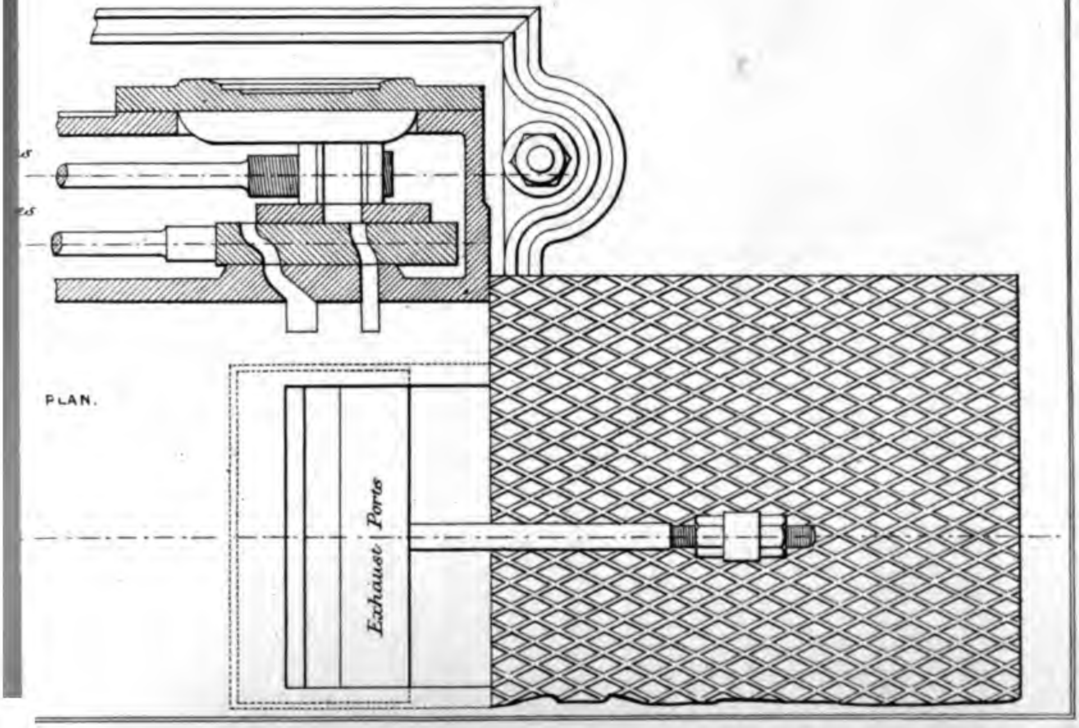
Newbery & Alexander lith. 42 Castle St Holborn

N OF THE STEAM & GOVERNOR GEAR TO REGULATE THE CUT-OFF.



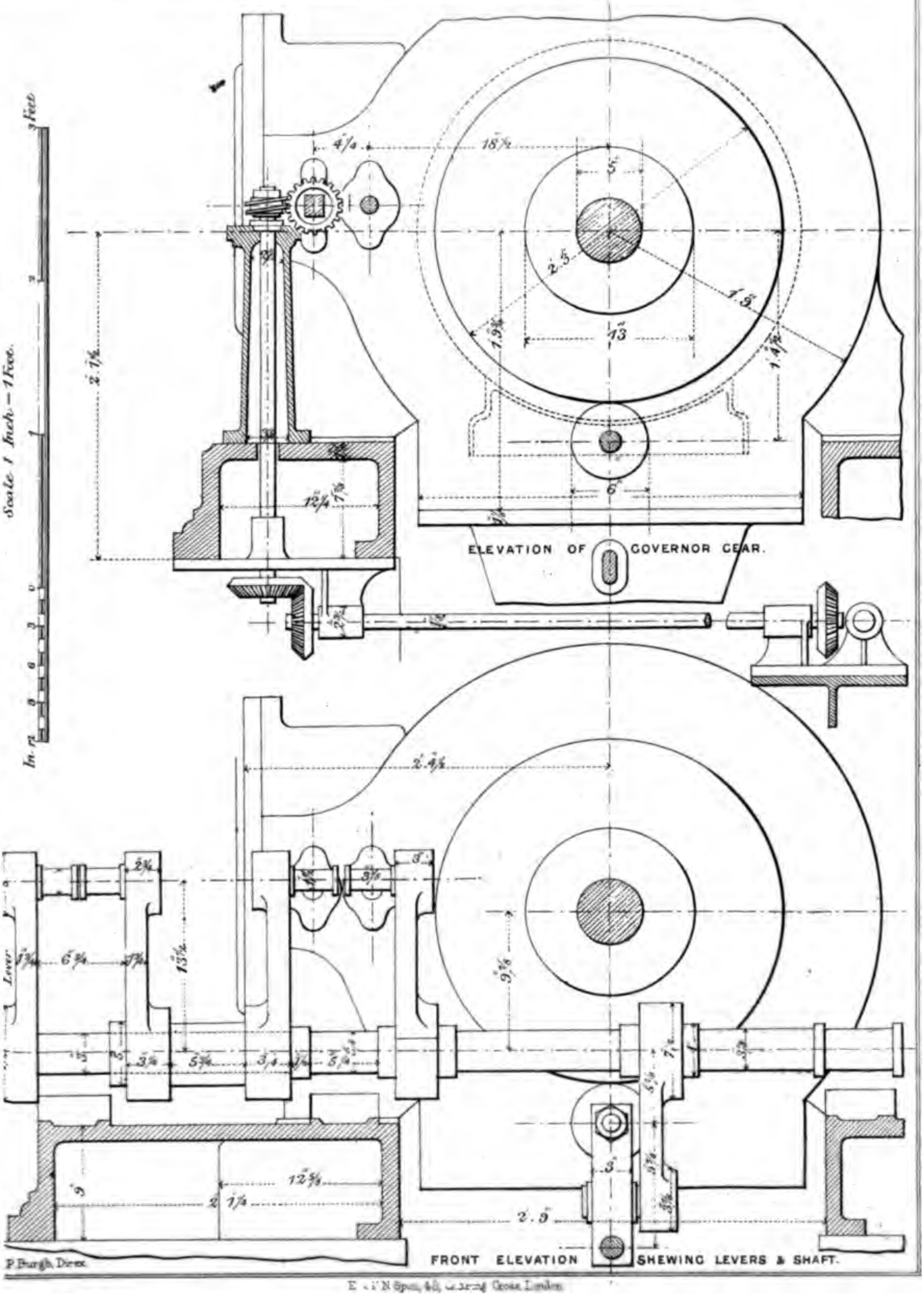
EVATION.

1 Inch — 1 Foot.



PLAN.

ELEVATIONS OF THE ENGINE SHOWN BY PLATE 53. BY MESSRS J & E. WOOD.



ELEVATION OF GOVERNOR GEAR.

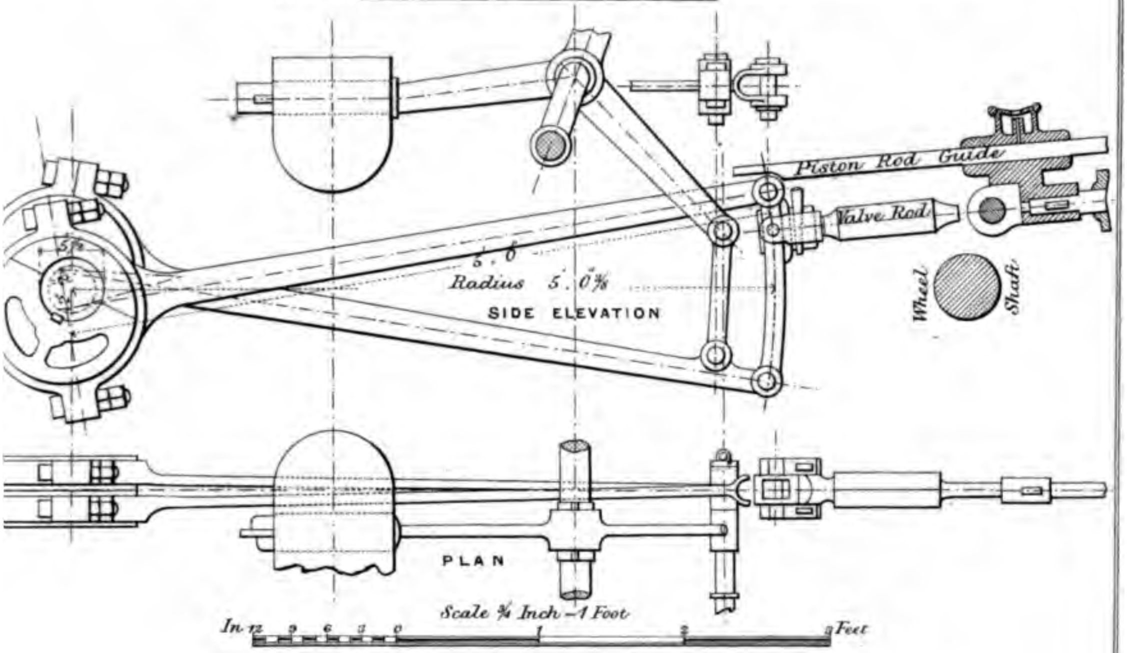
FRONT ELEVATION SHEWING LEVERS & SHAFT.

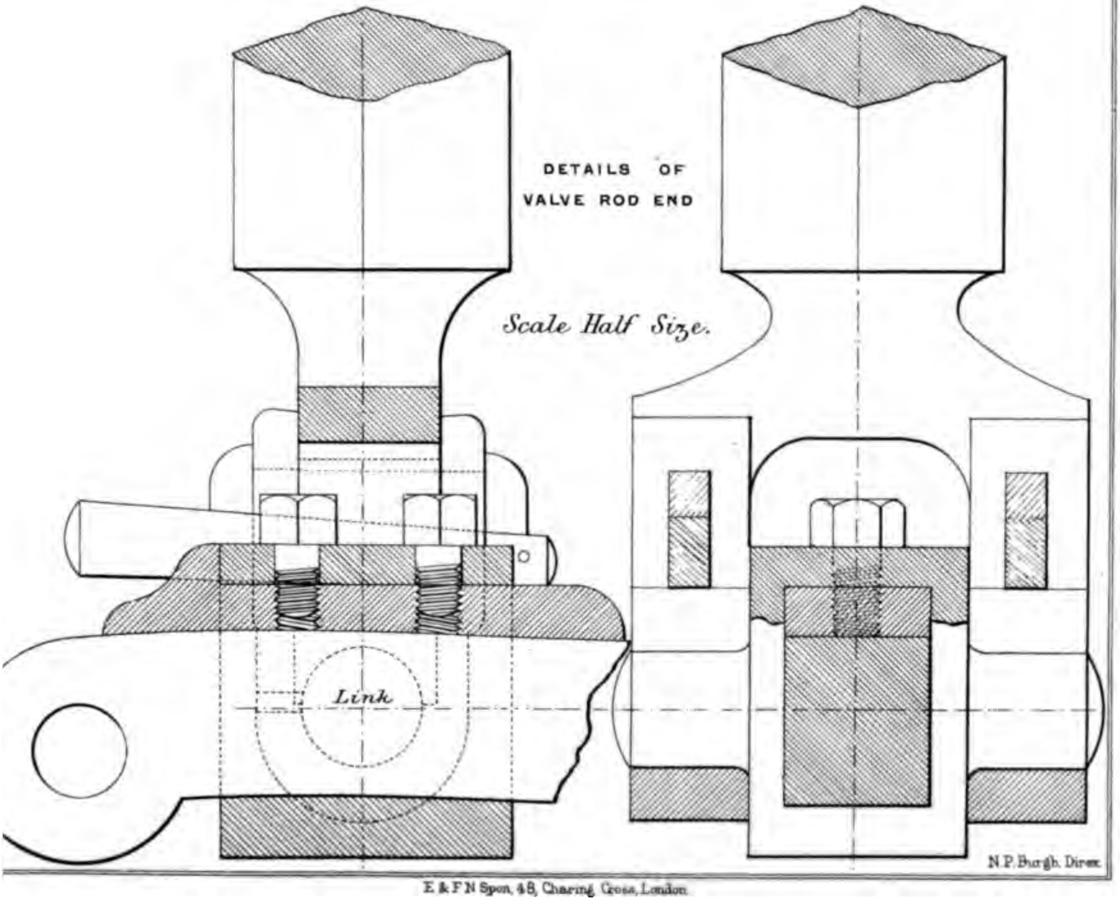
P. Burgh, Direx.

E. & F. N. Spon, 48, Charing Cross, London.

THE SOLID BAR LINK MOTION OF THE LOCOMOTIVE "KING-COIL" ARDROSSAN RAILWAY.

CONSTRUCTED BY WILLIAM ROBERTSON, 1851.

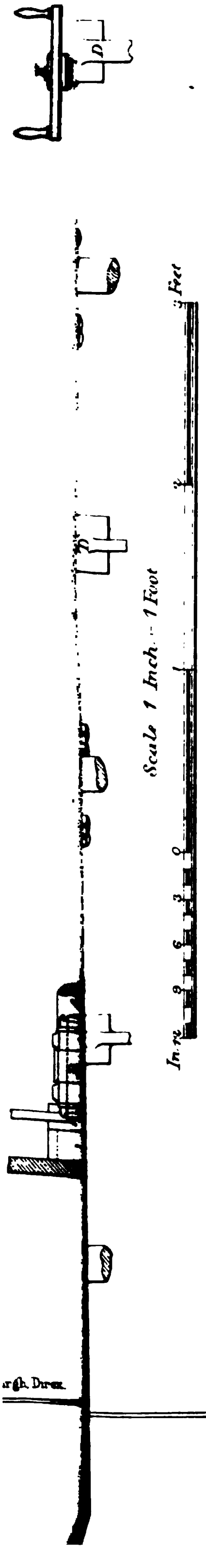




N.P. Burgh. Direx.

E & F N Spon, 48, Charing Cross, London.

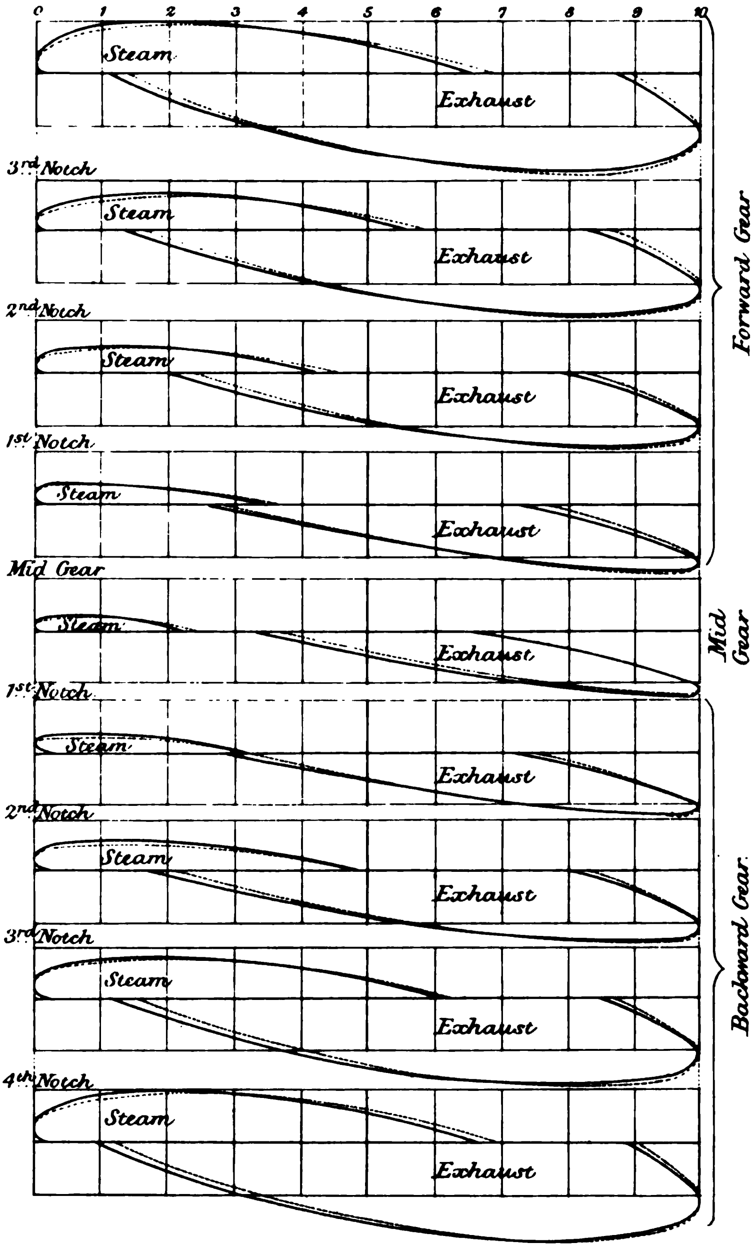
N AS APPLIED TO LOCOMOTIVE ENGINES.



DIAGRAMS SHEWING DISTRIBUTION OF STEAM.

Lap of Valve 1¼ Inch. Width of Steam Port 1⅜ Inch.

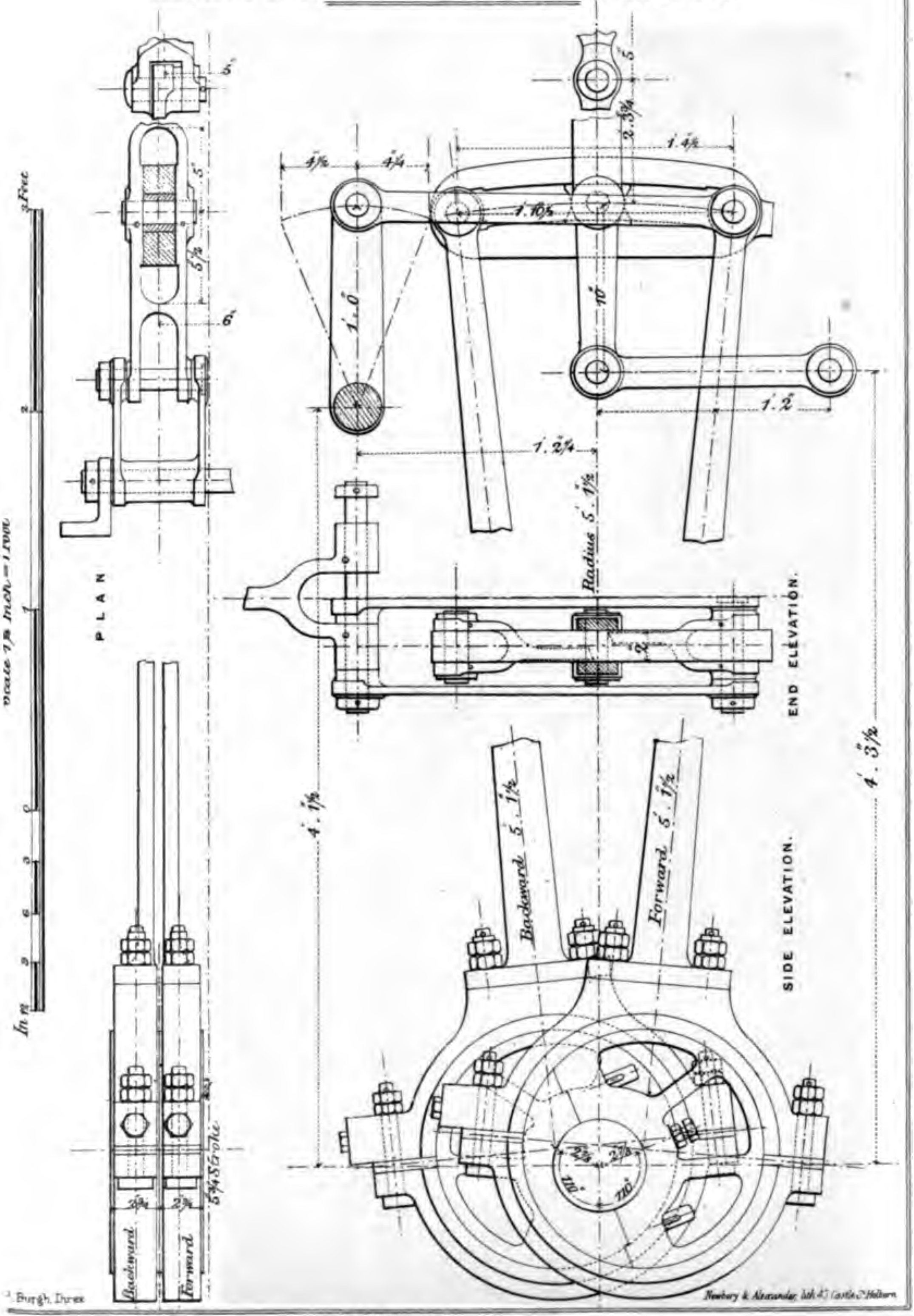
Throw of Eccentrics 5 Inches.



Newbery & Alexander lith 4 Castle S^t Holborn

ARRANGEMENT OF LINK MOTION FOR A LOCOMOTIVE.

CONSTRCTED BY MESSRS SHARP, STEWART & Cº LIMITED, 1867.

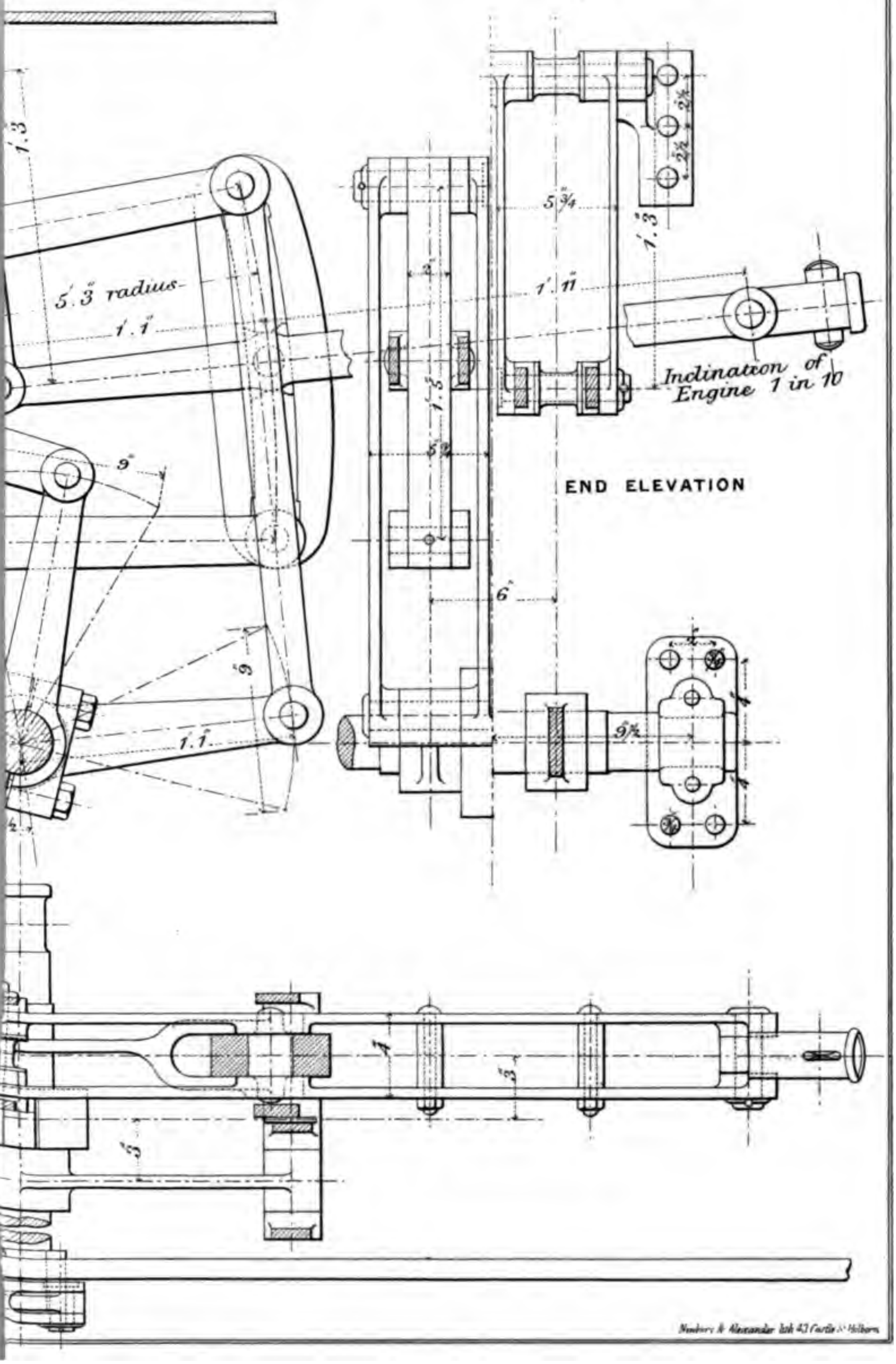


J. Burgh, Direx

Newbury & Alexander, lith 47 Castle St Holborn

E. & F. N. Spon, 48, Charing Cross, London

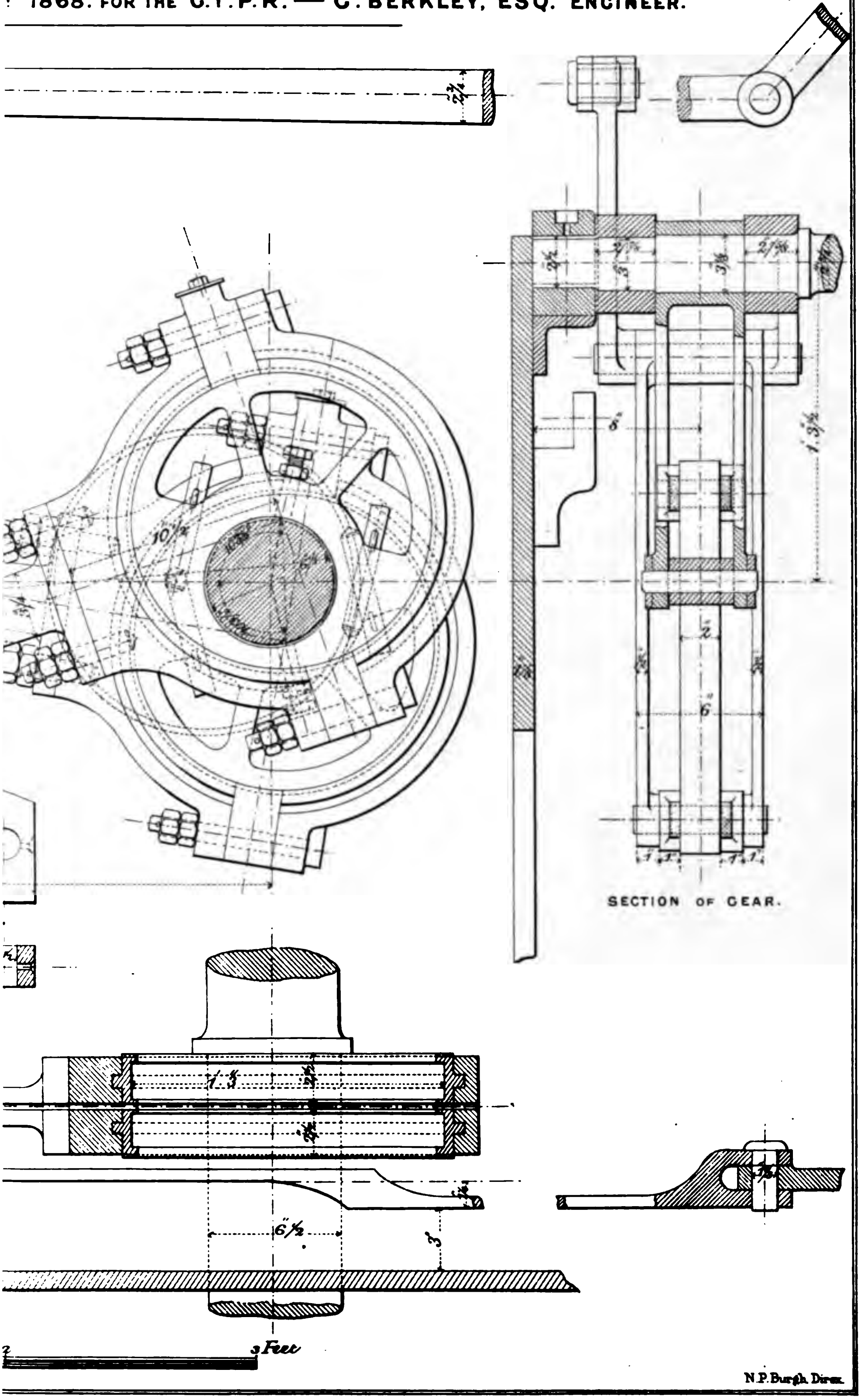
DUBS & C^o OF GLASGOW, JAN^Y 1868. FOR THE G.I.P.R.



Newbery & Alexander lith 43 Castle St Holborn

&C. OF A PASSENGER LOCOMOTIVE.

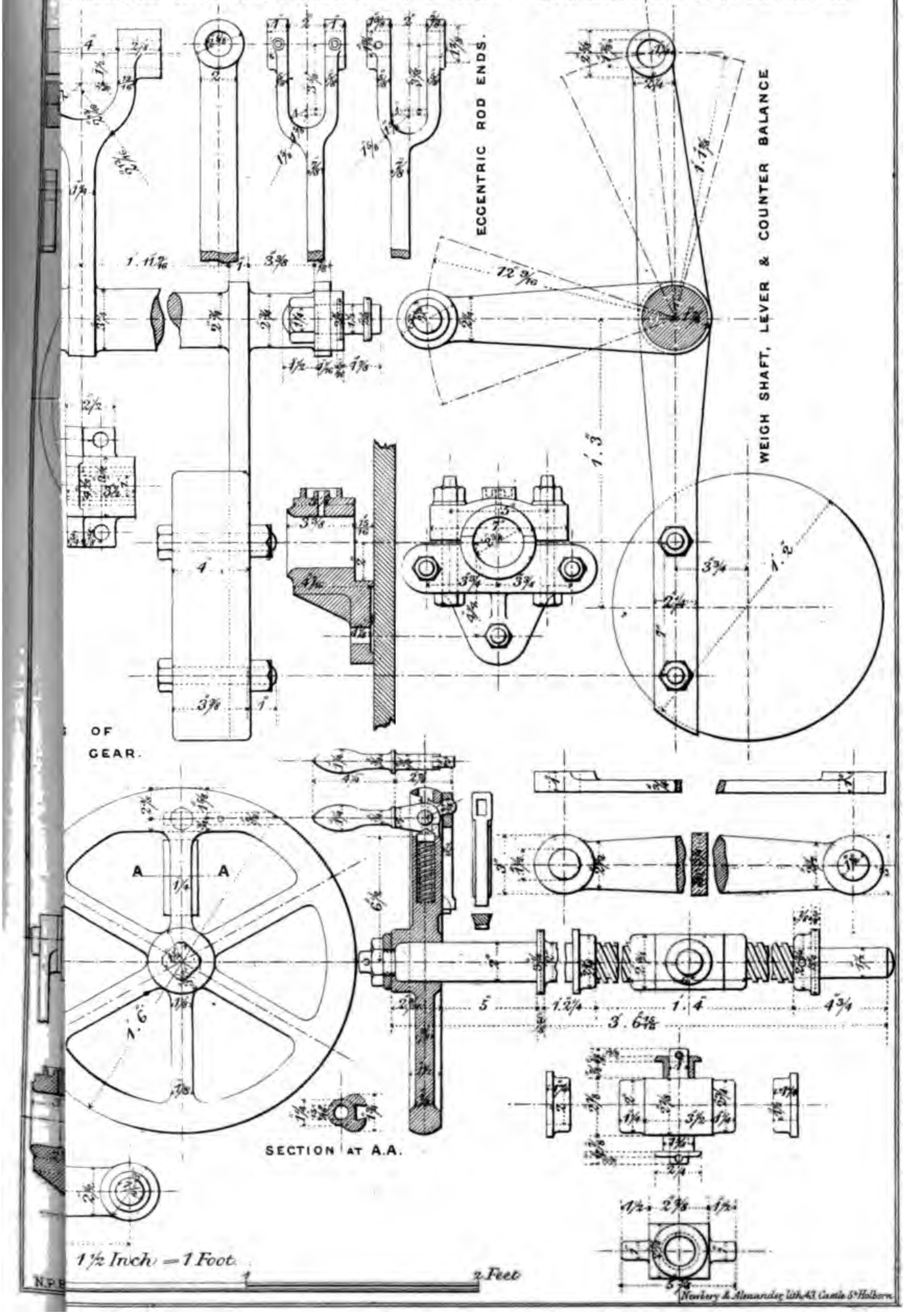
1868. FOR THE G.I.P.R. — G. BERKLEY, ESQ. ENGINEER.



SECTION OF GEAR.

N.P. Burgh Direx.

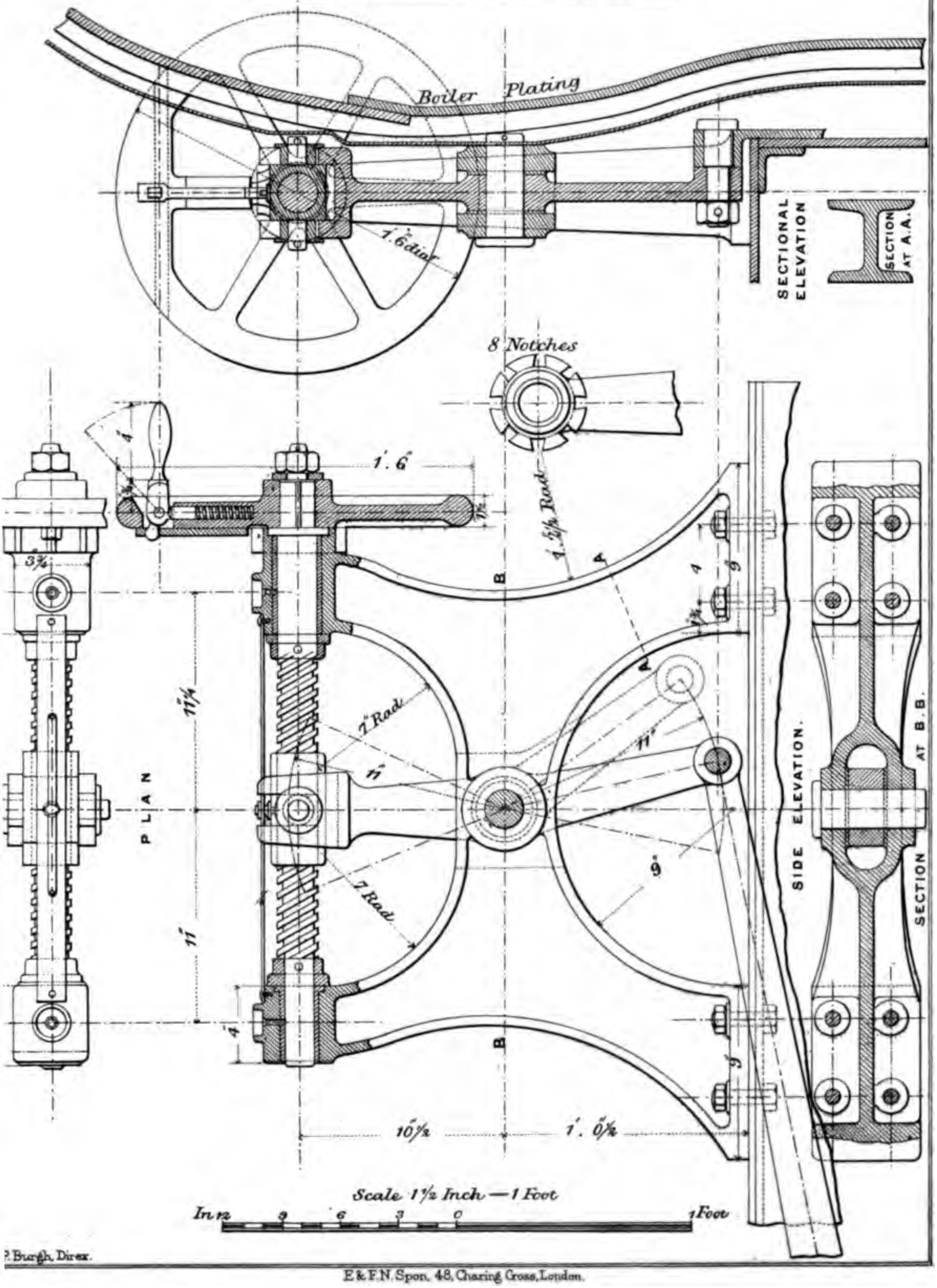
S KITSON & Cº LEEDS, FOR THE G.I.P.R. — C. BERKLEY, ESQ. ENGINEER.



Newbery & Alexander, lith. 43, Castle St Holborn.

REVERSING GEAR FOR GOODS ENGINE FOR THE G.I.P.R.

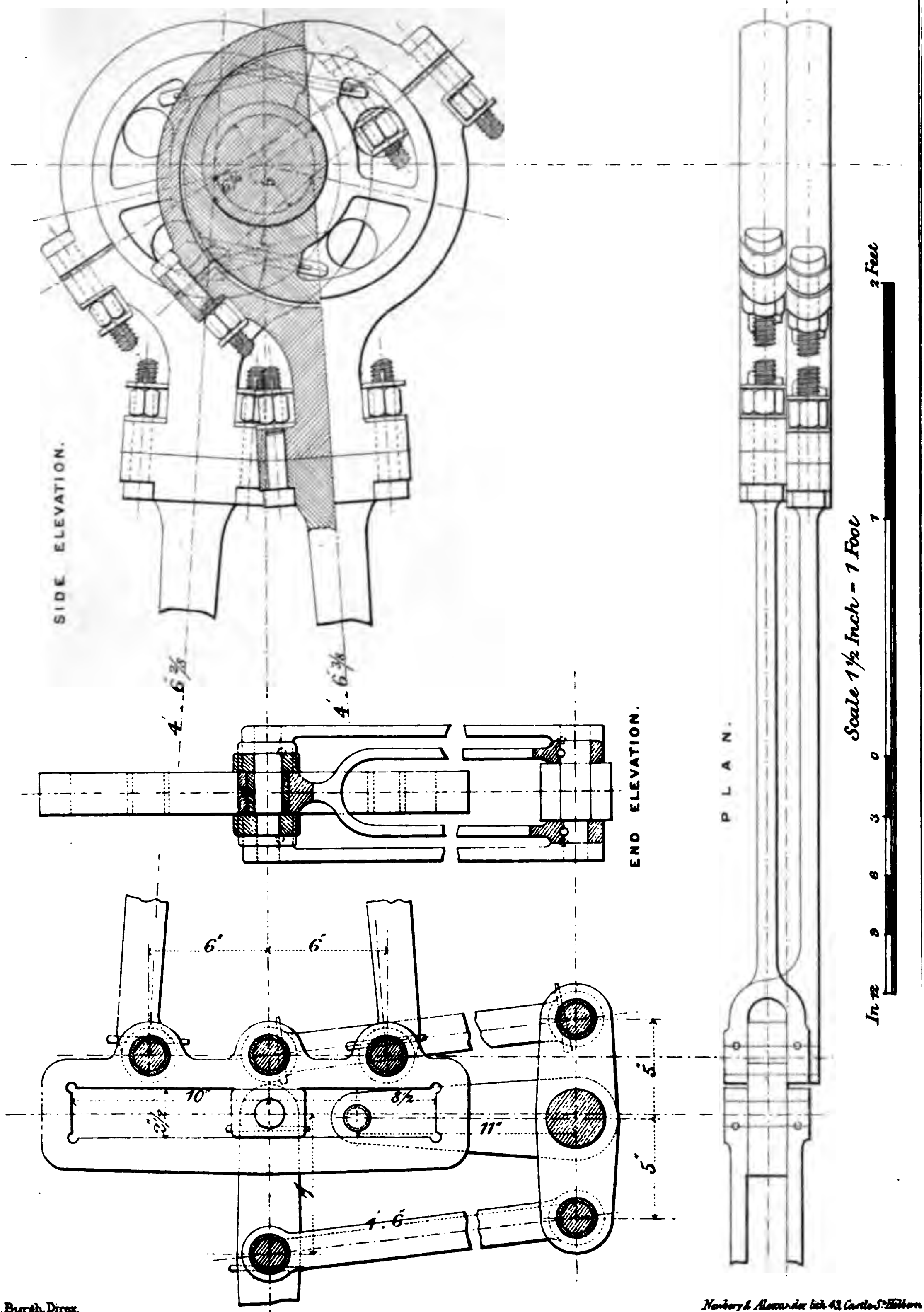
G. BERKLEY, ESQ. ENGINEER.



P. Burgh, Direx.

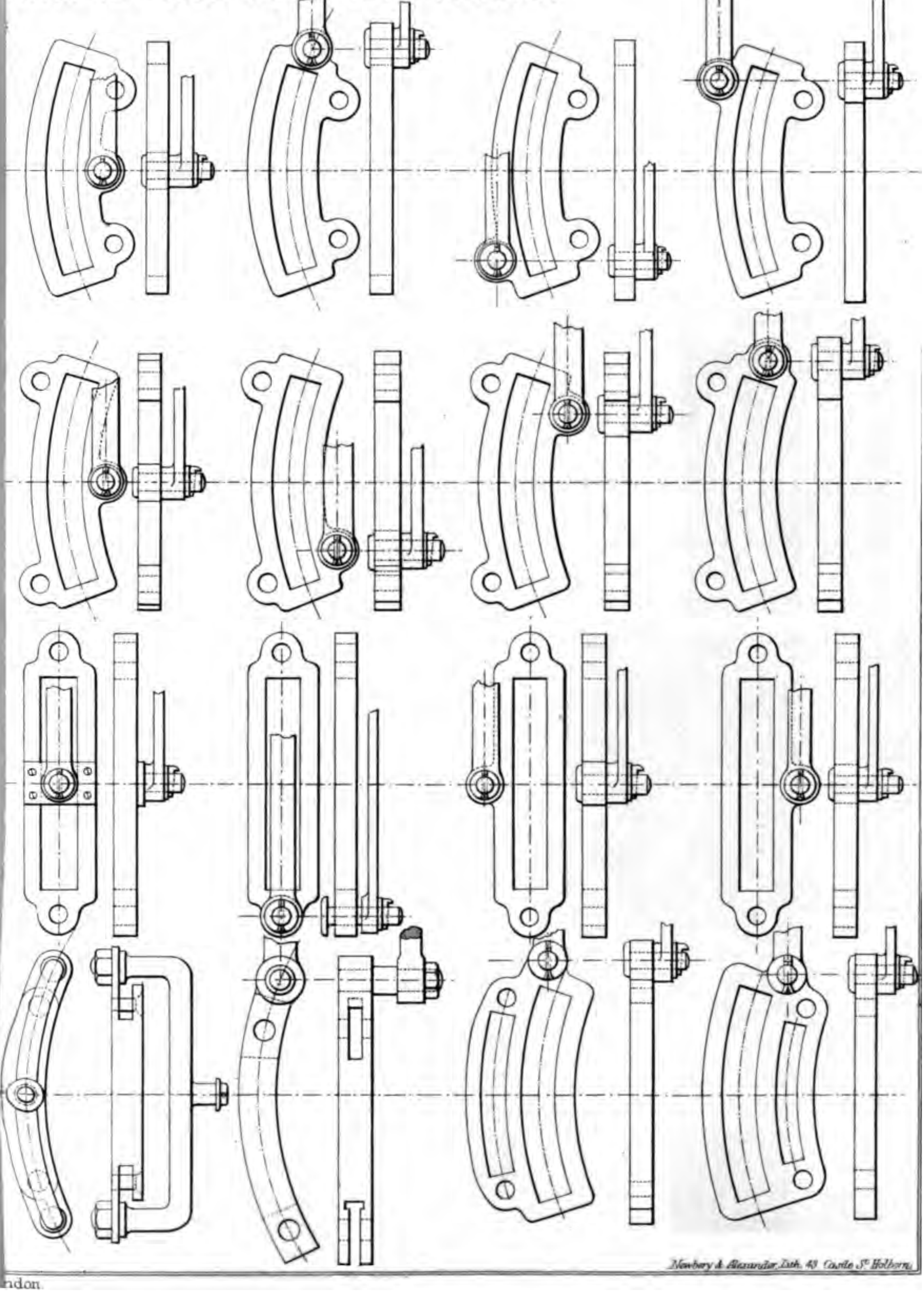
E & F.N. Spon, 48, Charing Cross, London.

ALLAN'S LINK MOTION AS CONSTRUCTED BY C.H. BEATTIE, ESQ. L & S.W.R. 1870.



Burgh, Direx.
Newbery & Alexander lith 43 Castle St Holborn
E & F. N Spon, 48, Charing Cross, London.

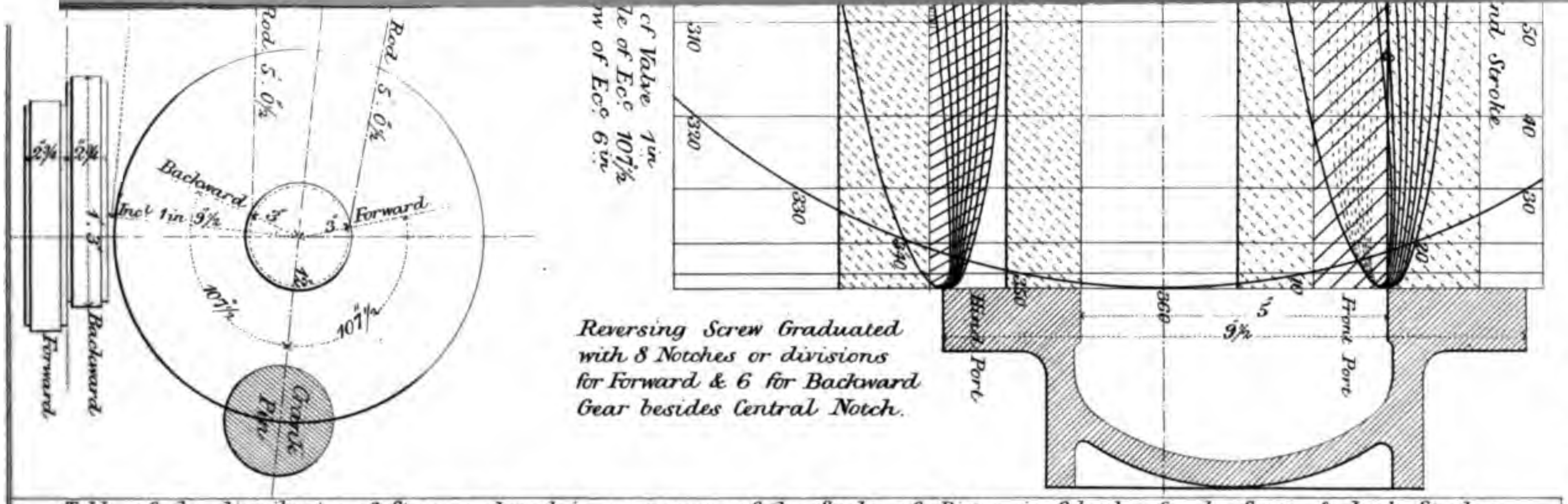
INKS AS USED FROM 1842 TO 1870.



Newbery & Alexander Lith. 43 Castle St Holborn

ndon.

E FOR THE C.I.P.R. C. BERKELY, ESQ. ENGINEER.



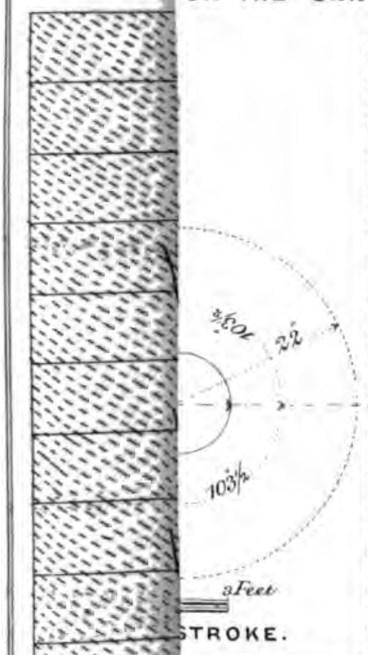
Reversing Screw Graduated with 8 Notches or divisions for Forward & 6 for Backward Gear besides Central Notch.

Table of the distribution of Steam reckoned in per centages of the Stroke of Piston in Cylinder for the front & back Strokes Respectively & in forward & backward Gear of the Link Motion

								FORWARD GEAR.							
	Front Stroke								Back Stroke						
	Effective pressure					Back pressure (on opposite side of Piston)			Effective Pressure				Back pressure (on opposite side of Piston)		
Notch	Travel	Lead	Full port	Admission	Expansion	Exhaust	Compression of Exhaust	Compression of Counter admission	Lead	Full port	Admission	Expansion	Exhaust	Compression of Exhaust	Compression of Counter-admission
1	4⅛ in	3/16 in.	15/16 in	71·5	20	8·5	8·5	0	3/16 in	1 3/16 in	70·5	19·5	9·5	9·5	·5
2	3 15/16	3/16	13/16	66	23·5	11	11	·5	3/16	1	65	22	12·5	12·5	·5
3	3 9/16	3/16 f	11/16	59	28	12·5	12·5	·5	3/16 f	13/16 f	59	26	14	14	1
4	3 5/16	⅛ b	9/16 f	51	32	16·5	16·5	·5	¼ b	11/16	52	29	18	18	1
5	3 3/16	¼	½	43	35	21	21	1	¼	9/16	44·5	32·5	21·5	21·5	1·5
6	2⅞	¼ f	7/16	35	37	26	26	2	¼ f	7/16 f	36·5	35	26	26	2·5
7	2¾	5/16 b	⅜ f	27	38	31	31	4	5/16 b	⅜ f	27·5	38	30	30	4·5
8	2⅝	5/16	5/16 f	19·5	37·5	36·5	36·5	6·5	5/16	5/16 f	20	38	35	35	7
								BACKWARD GEAR.							
1	3⅞	3/16 f	13/16	68·5	21	10	10	·5	3/16 b	1 1/16	70	18	11·5	11·5	·5
2	3½	¼	⅝ f	60	26	13·5	13·5	·5	3/16	13/16	63	22	14	14	1
3	3 3/16	5/16 b	½ f	51	31	17	17	1	¼ b	⅝ f	55	25	18	18	2
4	2⅞	5/16	7/16	40	36·5	21	21	2·5	¼	½	45·5	30	21·5	21·5	3
5	2 11/16	5/16	⅜ b	28·5	41	26·5	26·5	4	¼ f	⅜	34	35	25·5	25·5	5
6	2 9/16	5/16	5/16	17·5	42·5	32·5	32·5	7·5	¼ f	5/16	21	40	30	30	9

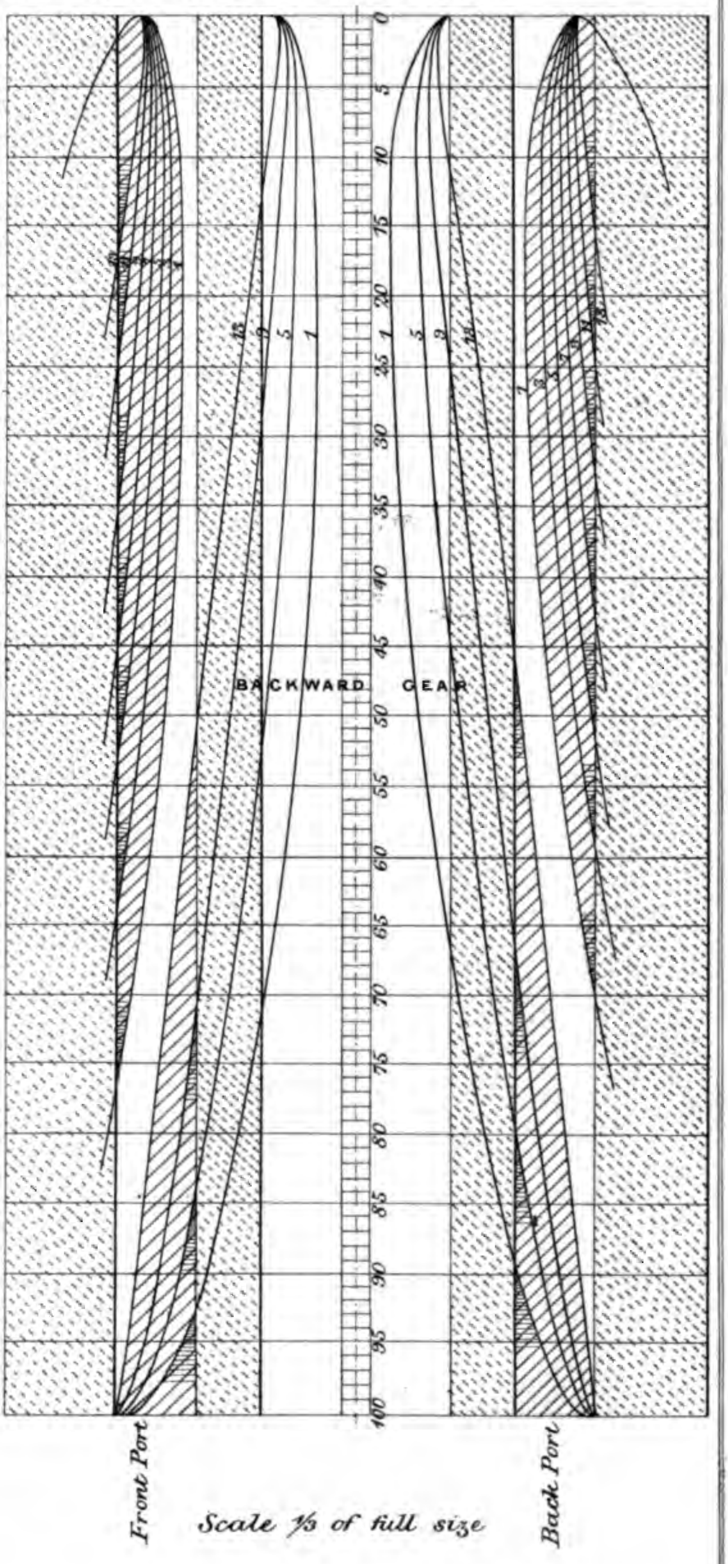
NOTE. In the Central notch the admission is 14 for the front & back Strokes in Forward Gear & 12 for the back & 10·5 for the front Stroke in Backward Gear.

ᖴOR THE G.I.P.R. G. BERKELY, ESQ. ENGINEER.



STROKE.

EAR.		
Leads		
P.	B.P.	
f	¼ b	1
	¼ f	2
f	5/16 b	3
b	5/16	4
b	5/16 f	5
	5/16 f	6
	3/8 b	7
f	3/8 b	8
f	3/8	9
f	3/8	10
f	3/8 f	11
f	3/8 f	12
f	3/8 f	13

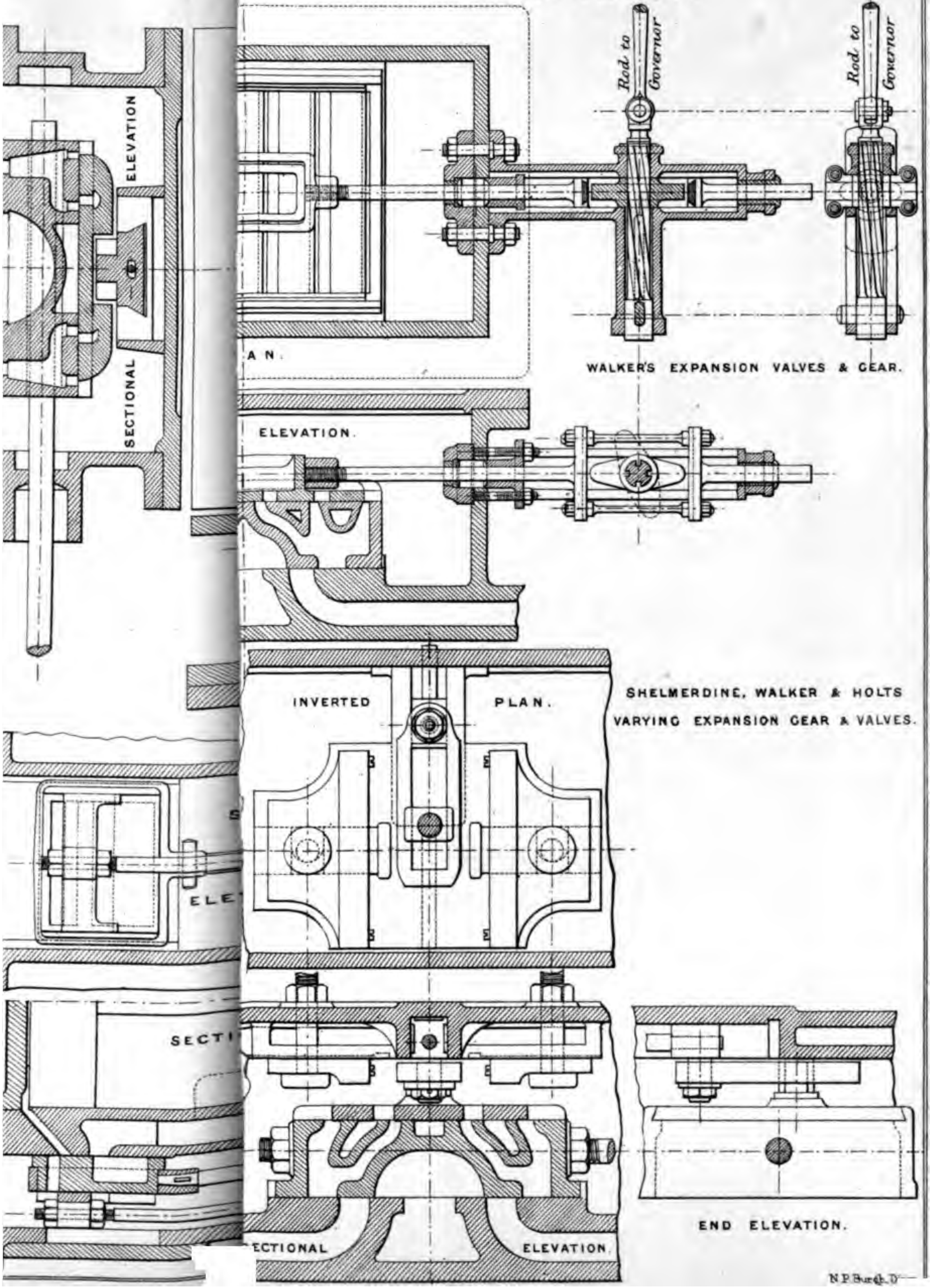


Scale ⅓ of full size

N.P. Burgh Del

Newbery & Alexander Lith. 43 Castle St Holborn

AR ERNORS FOR STATIONARY ENGINES.

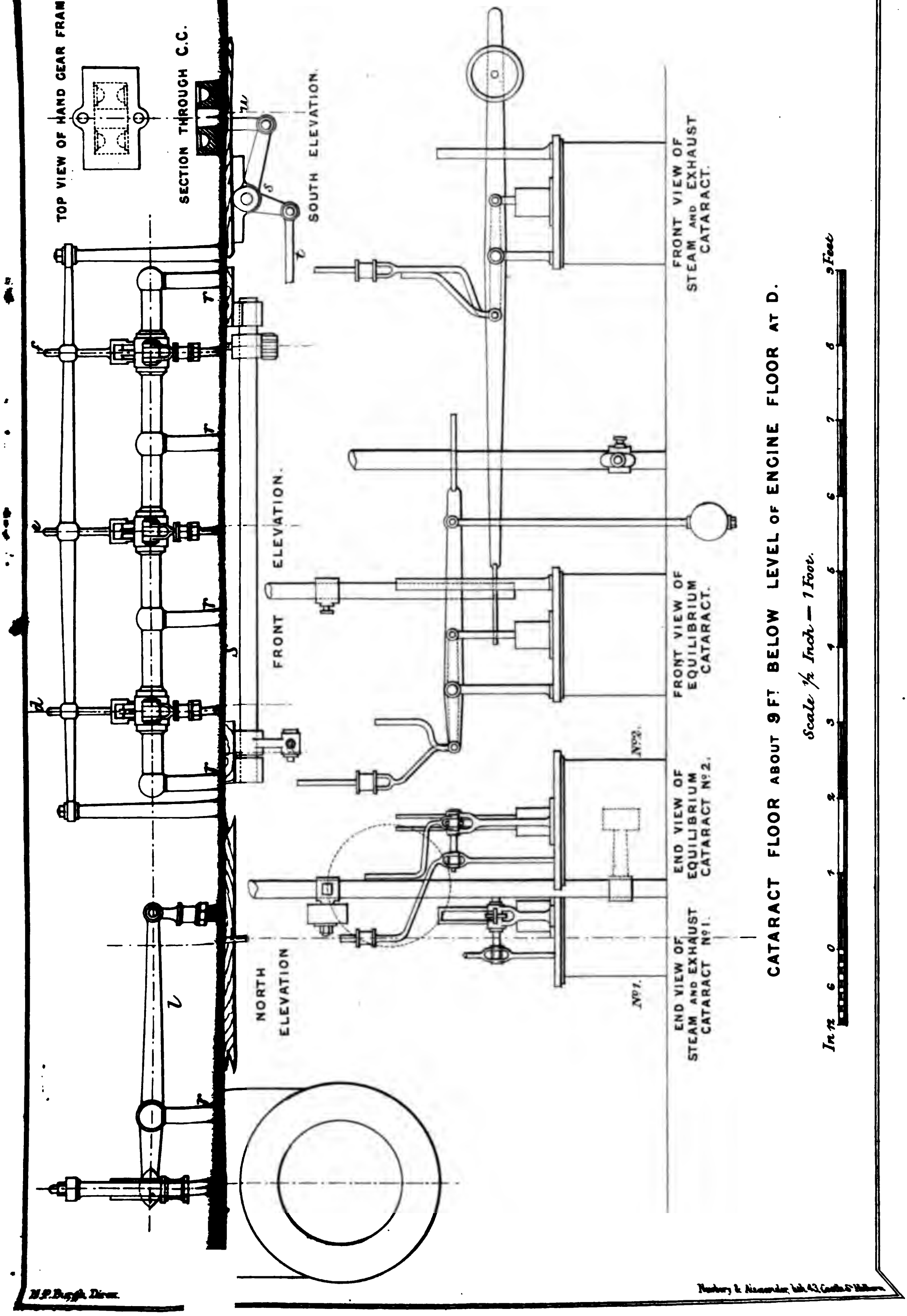


WALKER'S EXPANSION VALVES & GEAR.

SHELMERDINE, WALKER & HOLTS VARYING EXPANSION GEAR & VALVES.

N.P.Burgh D.

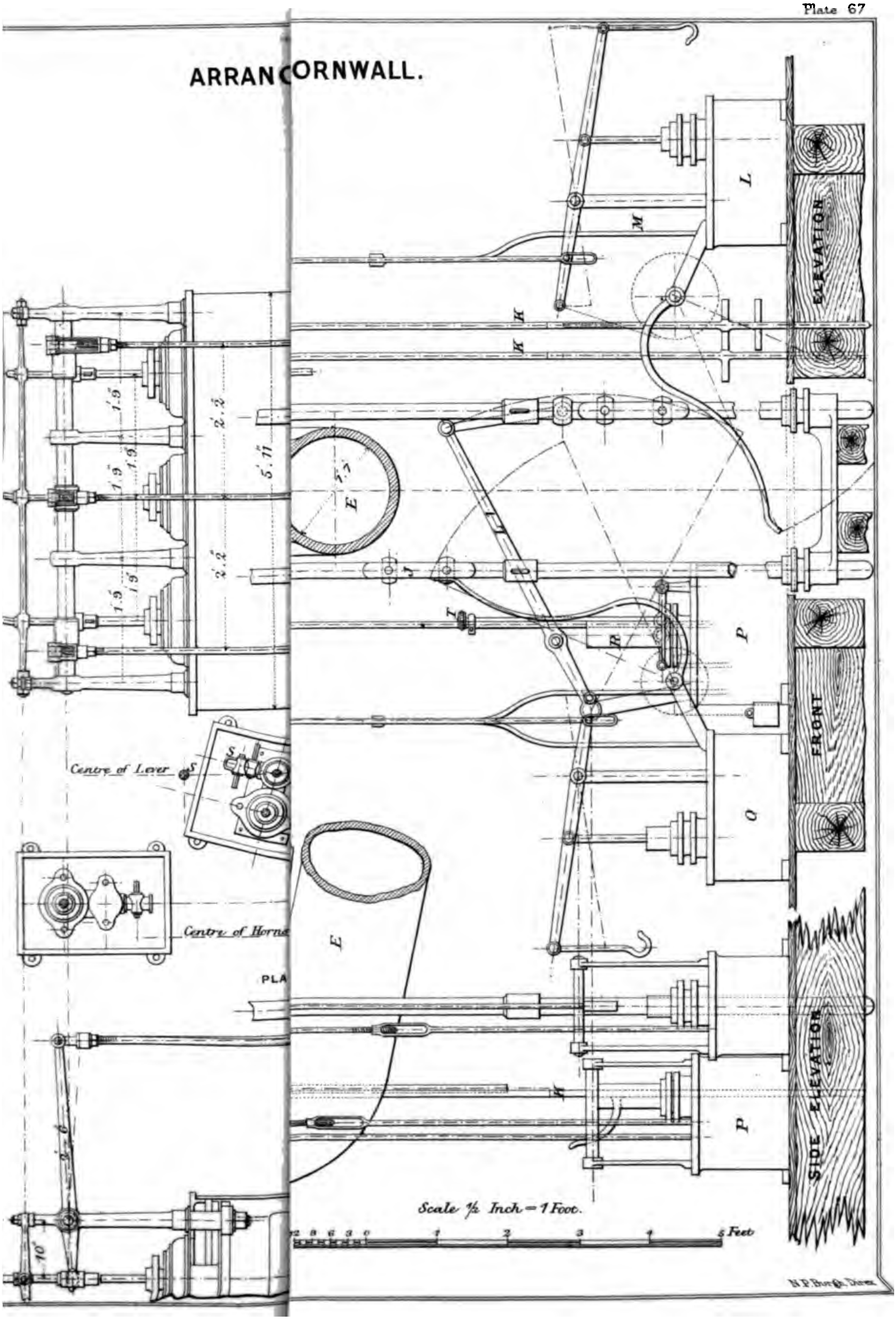
HA OWE, CLAY CROSS. FEBRUARY. 9TH 1862.


TOP VIEW OF HAND GEAR FRAME
SECTION THROUGH C.C.
SOUTH ELEVATION.
FRONT ELEVATION.
NORTH ELEVATION
FRONT VIEW OF STEAM AND EXHAUST CATARACT.
FRONT VIEW OF EQUILIBRIUM CATARACT.
END VIEW OF EQUILIBRIUM CATARACT No 2.
END VIEW OF STEAM AND EXHAUST CATARACT No 1.
No 2.
No 1.
CATARACT FLOOR ABOUT 9 FT BELOW LEVEL OF ENGINE FLOOR AT D.
Scale ½ Inch — 1 Foot.
Inns 6 0 1 2 3 4 5 6 7 8 9 Feet
u
s
t
r
f
e
d
l

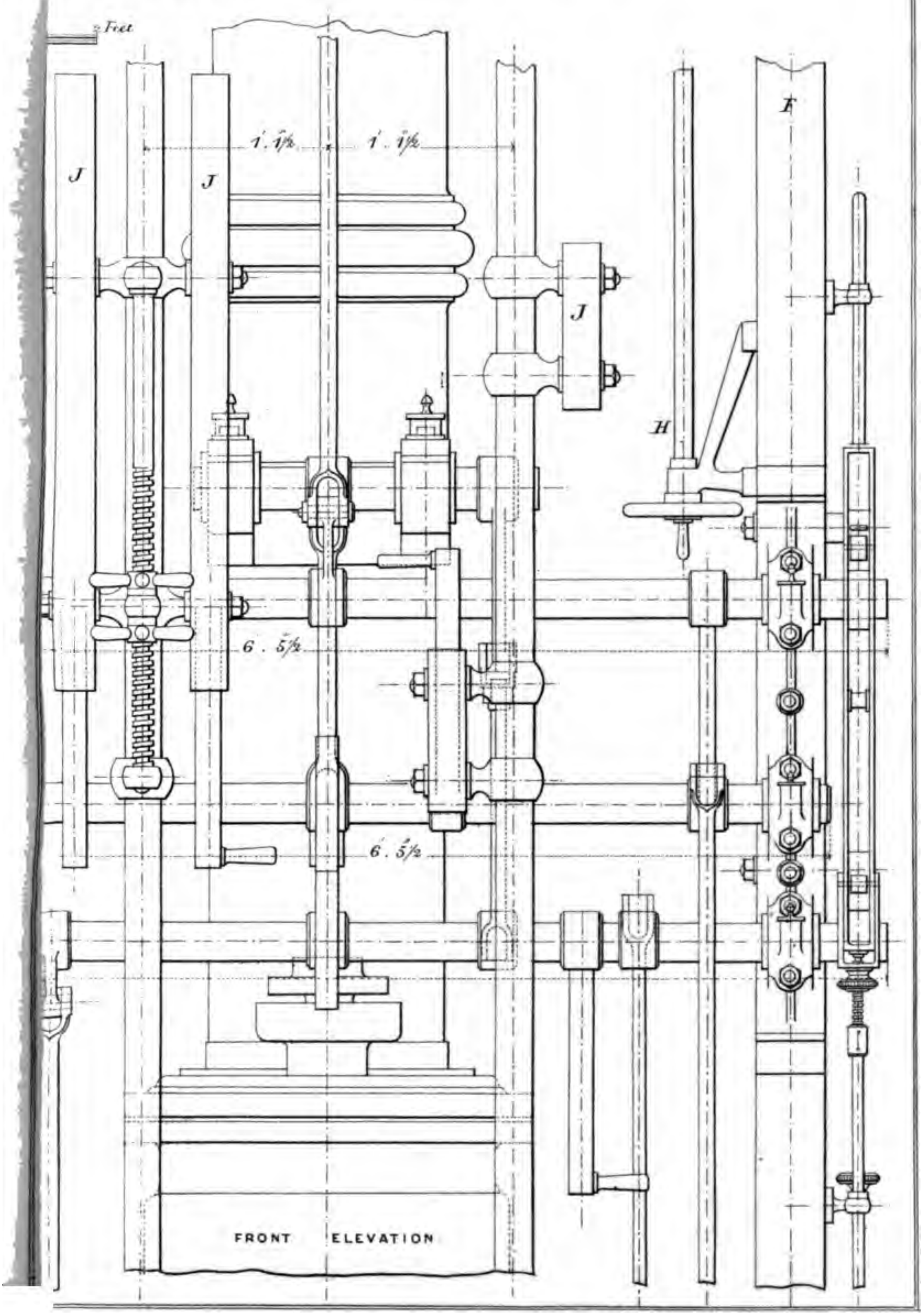
W.P. Bugge Direx.

Newbury & Alexander, lith. 43 Castle St Holborn

ARRAN CORNWALL.



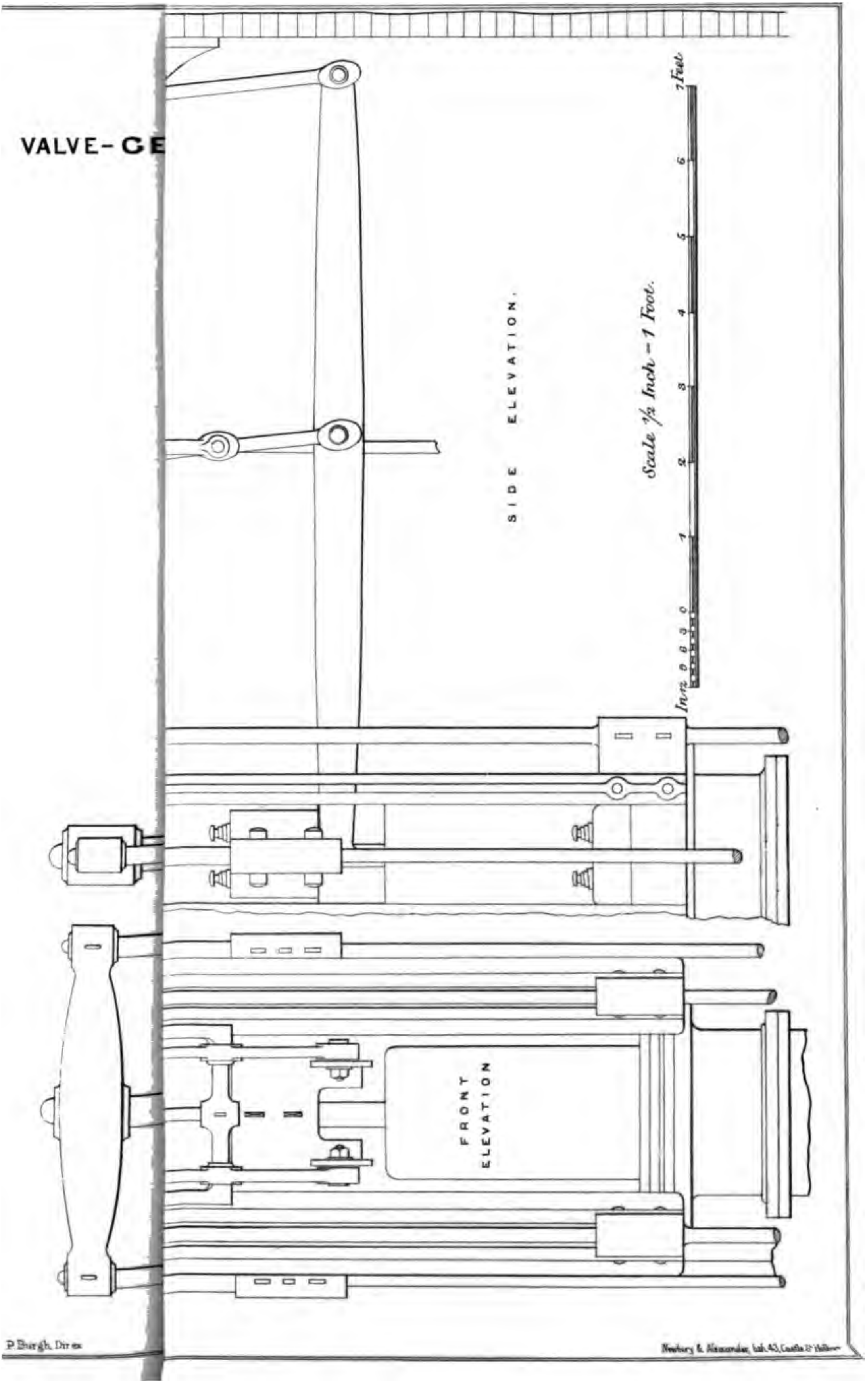
SSRS. HARVEY & CO. HAYLE, CORNWALL.



FRONT ELEVATION

Plate 6[illegible].

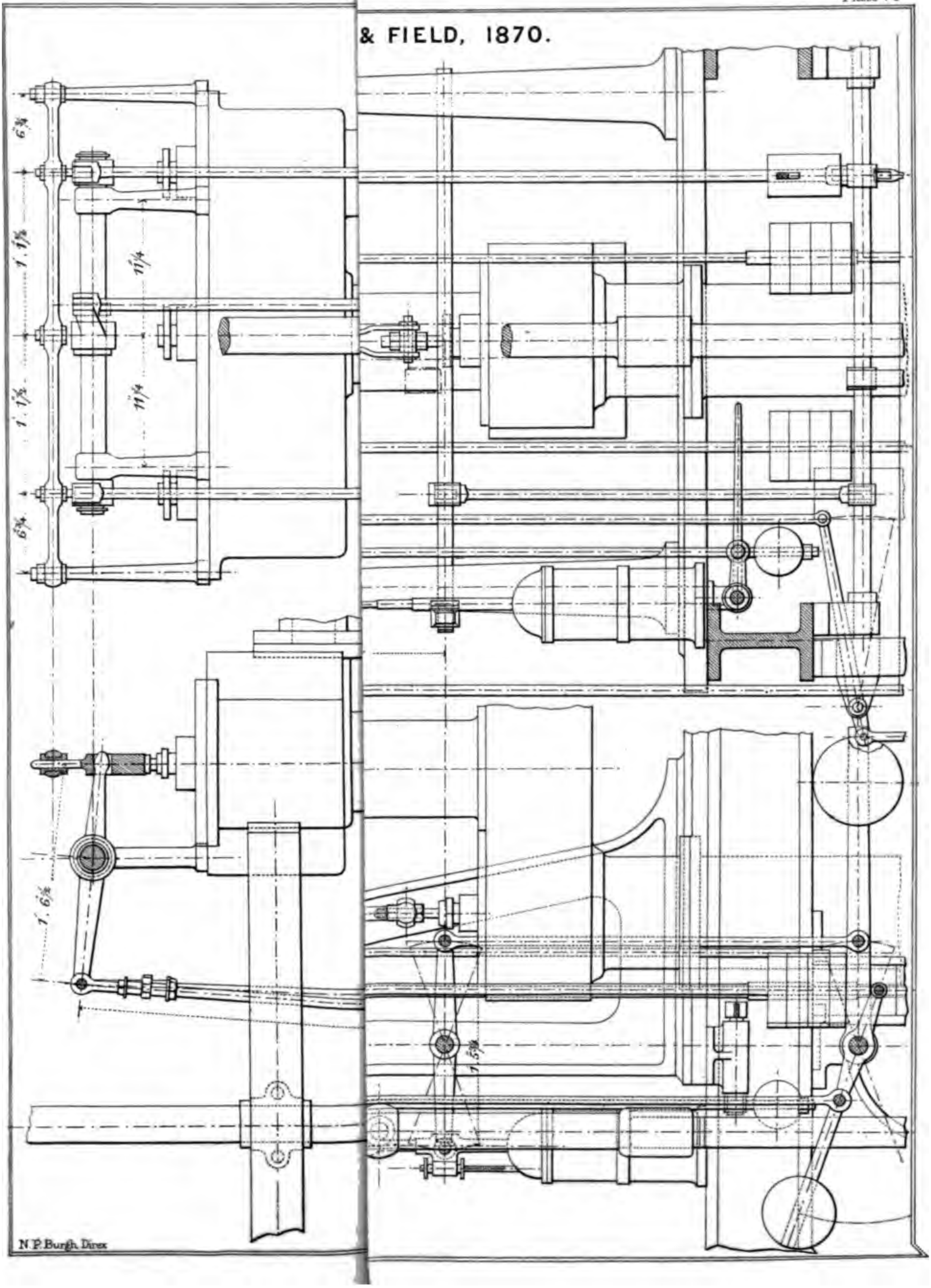
VALVE-GE



P. Burgh, Direx

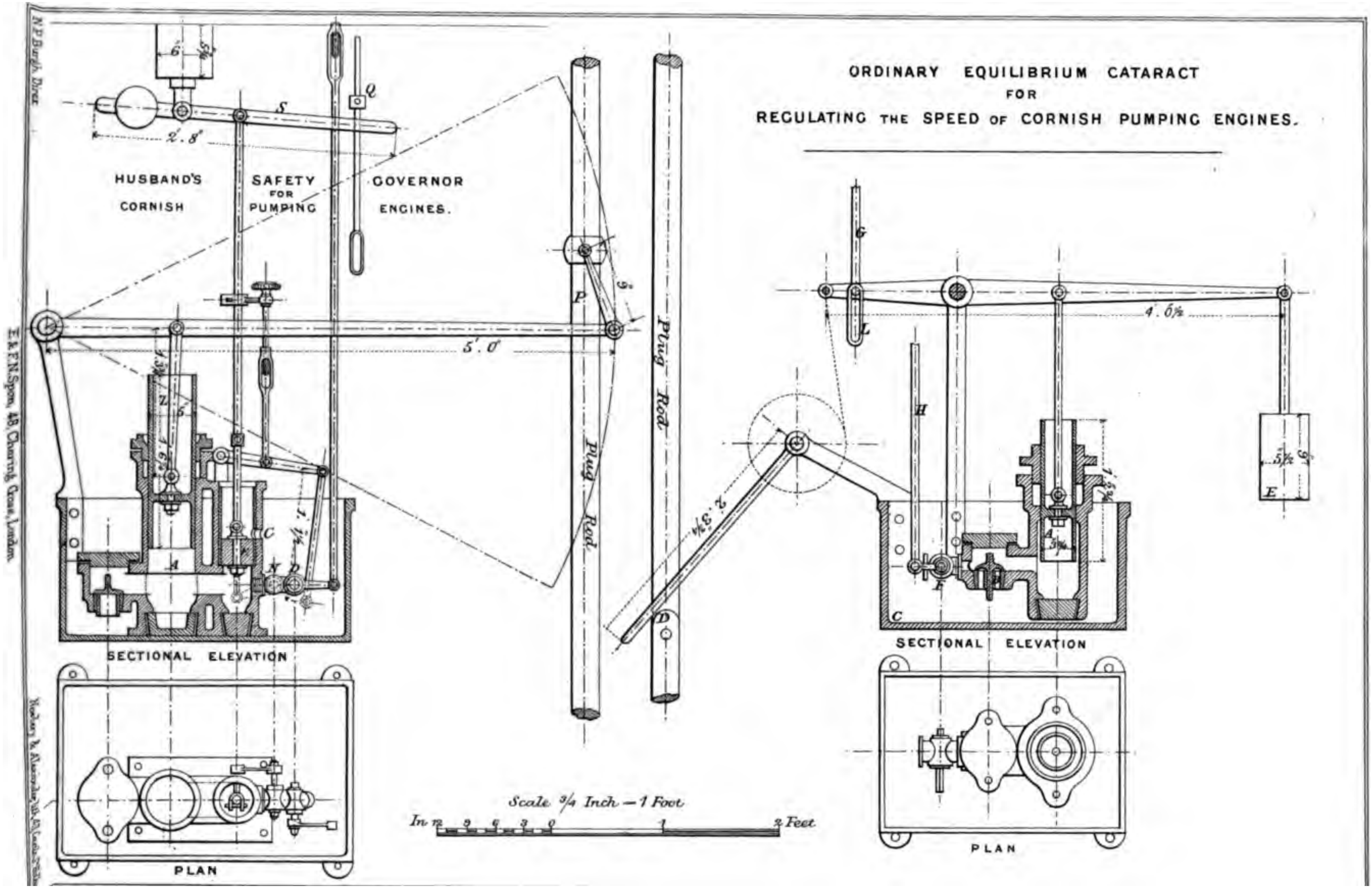
Newbury & Alexander, lith. 43, Castle St. Holborn

& FIELD, 1870.



N.P. Burgh. Direx

ORDINARY EQUILIBRIUM CATARACT FOR REGULATING THE SPEED OF CORNISH PUMPING ENGINES.


HUSBAND'S SAFETY GOVERNOR FOR CORNISH PUMPING ENGINES.

N.P. Burgh. Direx

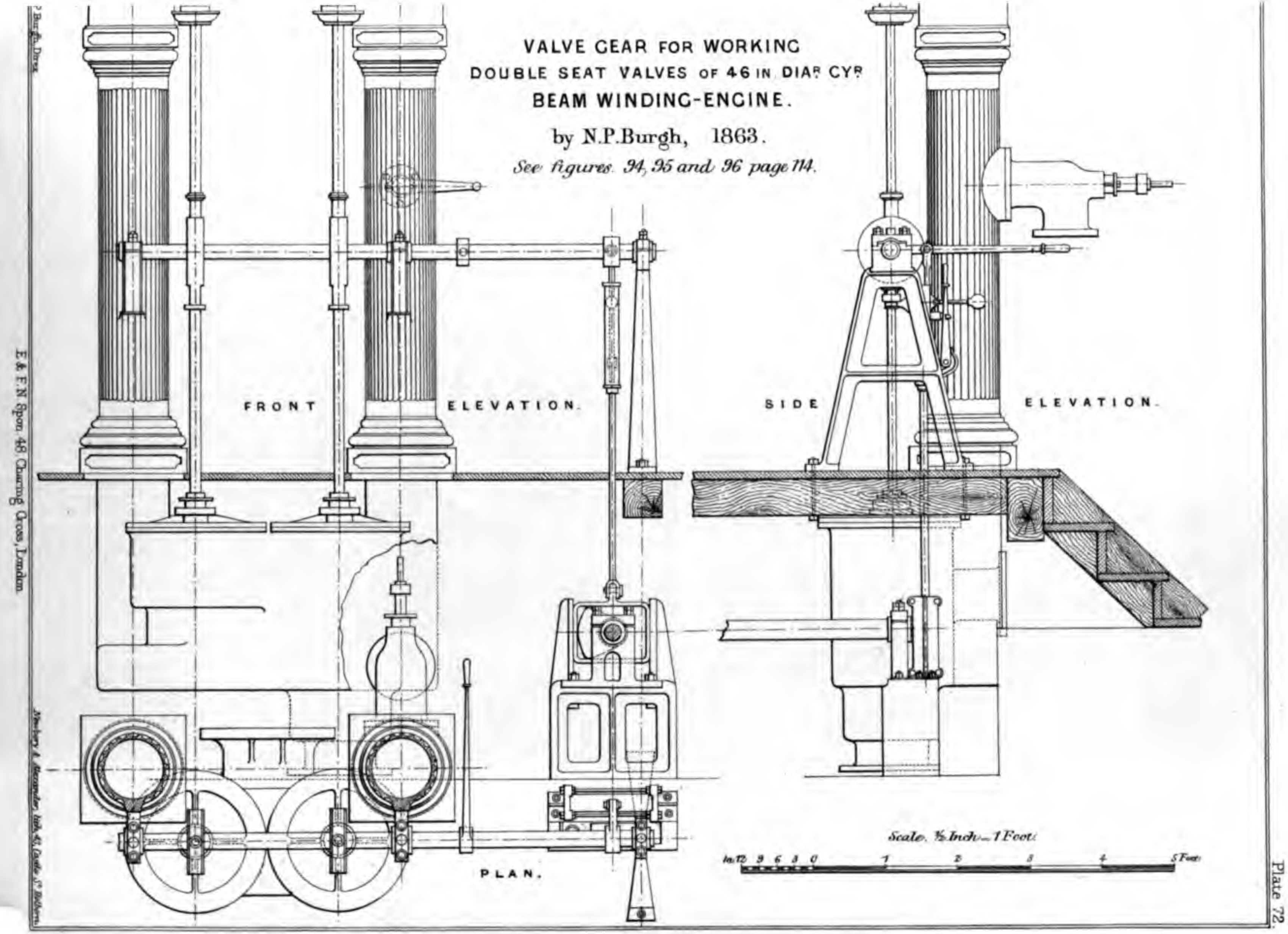
E. & F. N. Spon, 48, Charing Cross, London.

Newbery & Alexander, lith. 47, Castle St

VALVE GEAR FOR WORKING DOUBLE SEAT VALVES OF 46 IN. DIA? CY? BEAM WINDING-ENGINE.

by N.P.Burgh, 1863.

See figures. 94, 95 and 96 page 114.



P Burgh, Direx
Newbery & Alexander, lith. 43, Castle S^t Holborn.
E & F.N. Spon. 48. Charing Cross, London.